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Data Gap Analysis and Damage Case Studies: Risk Analyses from Construction and Demolition Debris Landfills and Recycling Facilities

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Notice

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Foreword

The US Environmental Protection Agency (US EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the Agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. To meet this mandate, US EPA's research program is providing data and technical support for solving environmental problems today and building a science knowledge base necessary to manage our ecological resources wisely, understand how pollutants affect our health, and prevent or reduce environmental risks in the future.

The National Risk Management Research Laboratory (NRMRL) is the Agency's center for investigation of technological and management approaches for preventing and reducing risks from pollution that threaten human health and the environment. The focus of the Laboratory's research program is on methods and their cost-effectiveness for prevention and control of pollution to air, land, water, and subsurface resources; protection of water quality in public water systems; remediation of contaminated sites, sediments and ground water; prevention and control of indoor air pollution; and restoration of ecosystems. NRMRL collaborates with both public and private sector partners to foster technologies that reduce the cost of compliance and to anticipate emerging problems. NRMRL's research provides solutions to environmental problems by: developing and promoting technologies that protect and improve the environment; advancing scientific and engineering information to support regulatory and policy decisions; and providing the technical support and information transfer to ensure implementation of environmental regulations and strategies at the national, state, and community levels.

This publication has been produced as part of the Laboratory's strategic long-term research plan. It is published and made available by US EPA's Office of Research and Development to assist the user community and to link researchers with their clients.

Cynthia Sonich-Mullin, Director
National Risk Management Research Laboratory

Table of Contents

List of Figures

List of Tables

Abbreviations and Acronyms

ADEM	Alabama Department of Environmental Management
ADEQ	Arkansas Department of Environmental Quality
APP	Aquifer Protection Permit
ATSDR	Agency for Toxic Substances and Disease Registry
C&D	Construction and Demolition
C&DD	Construction and Demolition Debris
C&DLF	Construction and Demolition solid waste Landfill
C/D	Construction/Demolition
C/DLF	Construction/Demolition-Inert Landfill Unit
CalRecycle	Department of Resources Recycling and Recovery (California)
$CaSO_4$	Calcium Sulfate
CCA	Chromated Copper Arsenate
CCDD	Clean Construction and Demolition Debris
C&D	Construction and Demolition
C&DD	Construction and Demolition Debris
CDD	Construction/Demolition/Debris
CDI	Construction & Demolition Debris and Inert Debris
CDIL	Construction, Demolition, and Industrial Landfill
C/DLF or C&DLF	Construction and Demolition Landfill
CESQG	Conditionally Exempt Small Quantity Generator
CFR	Code of Federal Regulations
CH_4	Methane
CIWMB	California Integrated Waste Management Board
cm	Centimeter
CO	Carbon Monoxide
COD	Chemical Oxygen Demand
CUP	Conditional Use Permit
CZS	Continuous Zone of Saturation
DMWM	Division of Materials and Waste Management
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FDOH	Florida Department Of Health
FFD	Fresno Fire Department

ft	Foot or Feet
GCL	Geosynthetic Clay Liner
GCTL	Groundwater Cleanup Target Level
GEMS	Groundwater Environmental Monitoring System
H_2O	Water
H_2S	Hydrogen Sulfide
HDPE	High Density Polyethylene
IL	Intervention Limit
ILF	Industrial Landfill Unit
in.	Inch or Inches
L	Liter
LAC	Louisiana Administrative Code
LEL	Lower Explosive Limit
MCL	Maximum Contaminant Level
MDE	Maryland Department of the Environment
MDEQ	Montana Department of Environmental Quality
MFA	Materials Flow Analysis
Mg	Magnesium
mg	Milligram
MPCA	Minnesota Pollution Control Agency
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
MSWLF	Municipal Solid Waste Landfill
NDEQ	Nebraska Department of Environmental Quality
NGVD	National Geodetic Vertical Datum
NMAC	New Mexico Administrative Code
NOV	Notice Of Violation
NRMRL	National Risk Management Research Laboratory
OAC	Ohio Administrative Code
OEPA	Ohio Environmental Protection Agency
ORD	Office of Research and Development
PBR	Permit-by-Rule
PCB	Polychlorinated Biphenyl
PM	Particulate Matter
ppb	Parts Per Billion

ppm	Parts Per Million
RCRA	Resource Conservation and Recovery Act
RTI	Research Triangle Institute
sec	Second(s)
SMCL	Secondary Maximum Contaminant Level
SO_4	Sulfate
TCEQ	Texas Commission on Environmental Quality
TDS	Total Dissolved Solids
tpd	Tons per day
TS/MRF	Transfer Stations and Material Recovery Facility
UFC	Uniform Fire Code
µg	Microgram
US	United States
US EPA	United States Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VOC	Volatile Organic Compound
WAC	Washington Administrative Code
WBJ	Waste Business Journal
WCHD	Warren City Health District
WDNR	Wisconsin Department of Natural Resources
yd^3	Cubic yard

Executive Summary

Construction and demolition (C&D) debris represents a major component of the non-hazardous solid waste stream in the United States and includes materials generated from road construction and related infrastructure projects as well as from the demolition, construction, or renovation of building structures. Although federal rules do not have mandates specific to C&D debris, there are several federal rules that indirectly address the management of C&D debris. The federal standards found in 40 CFR 257 include basic requirements to provide environmental protection, and landfills that receive conditionally exempt small quantity generator (CESQG) hazardous waste must meet certain requirements including location restrictions, groundwater monitoring, and corrective action, but bottom liners and leachate collection systems are not required. As part of rulemaking for 40 CFR 257 Subpart B in 1995, two reports were prepared that examined impacts of C&D debris landfills on human health and the environment. Generally, the reports suggested that risks are minimal, but the universe of information used to arrive at this conclusion was limited (e.g., 11 damage case studies out of a total 1,889 landfills were examined in one report).

Since 40 CFR 257 Subpart B rulemaking, substantially more information regarding operational practices, potential human health and environmental impacts, and risk factors related to C&D debris management has been documented. Additionally, research has been conducted examining the potential environmental impacts from the leaching of common components of C&D debris, as well as air emissions from the disposal of C&D components including gypsum drywall. Furthermore, the emergence of large processing facilities to recycle C&D debris has occurred, thus affecting the composition of C&D debris that is ultimately disposed of in landfills.

In light of the amount of additional information that has been documented related to potential or actual environmental impacts from C&D debris management, the US EPA commissioned an evaluation of C&D debris management in the US to update and expand upon previous analyses to include information on more recent cases of damage and potential impacts and expand the breadth of damages beyond groundwater and surface water impacts. The specific objectives of the evaluation were to

- evaluate current state regulations and broad statistics pertaining to C&D debris management in the US;
- gather information from states regarding areas of concern, if any, with respect to C&D debris management facilities and their impact on human health and the environment;
- identify and analyze data gaps between information collected as part of the CESQG rulemaking and current, readily available information regarding C&D debris management, including (but not limited to) environmental monitoring data and compliance and enforcement information for C&D debris disposal and recycling facilities; and
- conduct detailed damage case assessments at three sites identified as causing damage in the last 10 years with an expanded set of damage pathways in the analysis (e.g., groundwater, air emissions, and fires).

The state regulatory evaluation documented information regarding minimum requirements for liner systems, groundwater monitoring, and routine soil cover application. The review found several examples where flexibility in meeting the minimum requirements was provided based on the specific location of the facility, the waste acceptance rate of the facility, or the ultimate size of the facility. Twenty-six states require groundwater monitoring for all C&D landfills, while an additional 11 require groundwater monitoring on a conditional basis (i.e., landfill size, location). The number of states requiring groundwater monitoring increased by approximately 28% since the evaluation conducted by the US EPA in the mid-1990s. Seventeen states require an engineered liner system with a leachate collection system, and 26 states require the application of cover material on the landfill's active face at least weekly. Nine

states have rules specific to waste processing facilities that include C&D debris, while 10 states had rules specific to C&D recycling and processing facilities.

Publicly-available inventories of C&D debris management facilities and information from trade organizations and other databases were examined to estimate the number of active C&D debris disposal and recycling facilities in the US. An estimated 1,540 active C&D debris landfills and 512 active recycling facilities that only process C&D materials were identified. The number of active C&D landfills was approximately 18% less than the inventory developed by the US EPA in 1994. The decline may be attributable to several factors, including increased stringency in C&D rules at the state level as well as closure of facilities following the economic downturn that began in late 2008, which greatly impacted the construction industry.

The C&D damage case inventory was developed based mostly on discussions with state solid waste regulatory staff and other publicly-available information (e.g., public hearing notices). In this examination, "damage" was defined as facilities with groundwater impacts, recurring odor problems, recurring fire problems, or other issues at the facility that impacted human health and the environment.

A total of 44 damage sites were identified, including facilities located in 17 different states covering eight of the 10 US EPA regions. The majority of the facilities identified as having caused damage were C&D disposal facilities. The number of actual damage sites is likely more than 44 because the inventory relied on opinions of state regulatory representatives at the headquarters level (i.e., site compliance and damage issues is handled at a more local or district level). The universe of damage sites examined was limited to active or recent issues, thus historical damage was not captured. Finally, the number of damage cases identified may have been limited because of the subjective nature of the term "damage", which could lead regulatory personnel to respond differently based on their individual experience and interpretation of the term.

Large-scale environmental compliance and monitoring data sets were reviewed from six states to examine a broader picture of information related to actual or potential damage from C&D management. The six states evaluated were Florida, Maryland, Minnesota, Ohio, Virginia, and Wisconsin. Several key observations were made as a result of the large data set review. First, data from several states showed evidence of groundwater impacts. Notably, many impacts were observed in states that had been identified has having few or no damage sites. Data compiled by the Ohio EPA showed that many chemicals measured in MSW landfill leachate were found at similar levels in C&D debris leachate (and in some cases greater). A comparison of information collected before and after promulgation of liner and leachate collection system rules in Maryland indicates that these measures have reduced the frequency and magnitude of groundwater impacts at C&D landfills in the state.

Three C&D debris management facilities were selected for a detailed damage case evaluation, with the intent of evaluating historical permitting documentation, inspection records, and environmental monitoring data to further understand the confluence of factors that led to damage, with particular focus on issues caused by permit non-compliance and issues that would have occurred even if the facility operated in compliance with its permit. The three facilities included the Saufley Landfill (C&D landfill in Florida), the Archie Crippen Excavation Site (C&D recycling facility in California), and the Warren Recycling Landfill (C&D landfill in Ohio). Ultimately, the examination found permit non-compliance was not the only contributor to the damage issues observed at each site.

The results of the analysis show that a variety of issues can occur at C&D management facilities. The inventory of damage sites in the US was limited by several factors, but the examination of large-scale statewide data suggests that the universe of C&D sites impacting the environment is likely far greater than the inventory developed through contacts with state regulatory representatives. The detailed assessment of

three damage cases each showed that a combination of factors, both related and unrelated to permit non-compliance, played a significant role in causing damage.

In light of these observations, it is recommended that the findings of this report be augmented by the following actions: survey those directly involved with compliance and enforcement of facilities (i.e., regulatory staff at the district, regional, or local level) to create an enhanced damage site inventory in the US, compile and examine additional large-scale data sets from other states in the US to provide a more complete picture of the ranges of constituent concentrations in C&D leachate and in groundwater at C&D management facilities, develop an improved inventory of C&D recycling facilities, and develop an improved inventory of the quantity of C&D debris managed in the US (disposal and recycling) to allow for improved management benchmarking similar to that which has been done for MSW for several years.

1. Introduction and Background

1.1 Background on C&D Debris Management

Construction and demolition (C&D) debris is generated from the construction, renovation, repair, and demolition of structures such as residential and commercial buildings, roads, and bridges. The composition of C&D debris varies based on the activity type and structure. In general, C&D debris is mainly comprised of concrete, wood products, metal, asphalt, drywall, and masonry products; other components often present in significant quantities include paper, earthen materials, and vegetative debris. Trace quantities of C&D debris may include paints, solvents, adhesives, and other related chemical products. C&D debris can be disposed of in landfills (either dedicated C&D landfills or co-disposed with other wastes such as MSW) or recovered for recycling.

Attempts have been made to estimate the amount of C&D debris generated annually in the United States (US), and results vary depending on the assumptions built into the estimate methodology. ***Figure 1-1*** presents a summary of three studies conducted to estimate C&D debris generation in the US. Earlier estimates of C&D debris generation by the US Environmental Protection Agency (US EPA) (1998 and 2009) used an assumed waste weight per construction activity area to calculate C&D debris generation, with estimates of 136 million and 170 million tons in 1996 and 2003, respectively. A limitation of these estimates is that they do not account for the large volume of infrastructure-related C&D debris that is generated in the US. A study conducted by Cochran and Townsend (2010) used a different approach to estimate C&D debris generation that relied on a materials flow analysis (MFA) approach and included all C&D debris (building-related and infrastructure-related). The MFA approach, which is similar to the methodology used by the US EPA to estimate the annual generation rate of MSW in the US, accounted for the consumption of construction materials in the US, assumed typical waste factors used for construction materials purchasing, and estimated the material service life to calculate the mass of C&D debris generated in the US. Based on the assumptions used, a range of 680 million to 860 million tons of C&D debris generation was estimated for the year 2002. As a point of comparison, the estimate of the MSW generation in the US in 2003 was approximately 236 million tons (US EPA 2005). More accurate estimates (such as compiling data collected from disposal and recycling facilities in the US) is difficult since many areas (states and local regulatory agencies) do not require tracking of waste amounts received at landfills.

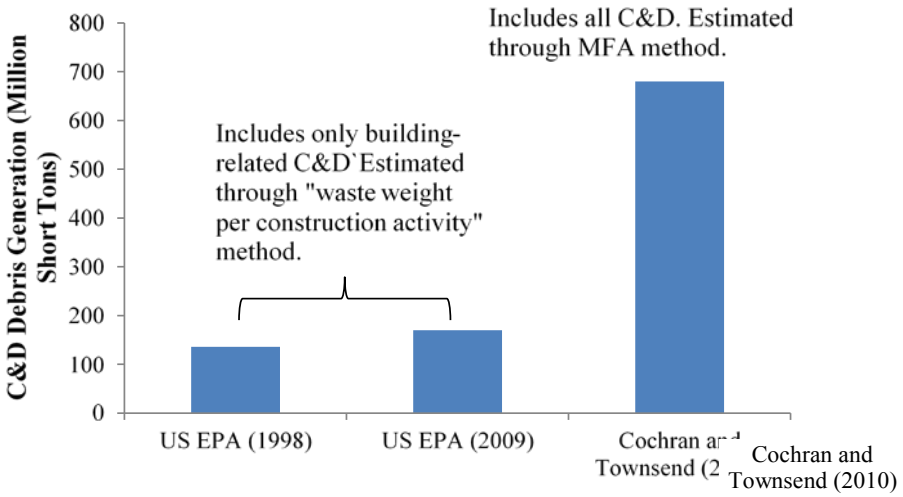

Figure 1-1. Previously Reported Annual Estimates of C&D Debris Generation in the US

In many cases, design and construction requirements for dedicated C&D debris disposal facilities are less stringent than federal requirements found in Title 40 Code of Federal Regulations (CFR) Part 258 (Subtitle D requirements) (e.g., no bottom liner or leachate collection and removal system), which often allows this method of disposal to be less expensive for a waste generator compared to other types of disposal facilities, which in turn can represent an economic disincentive to recycling. Furthermore, the absence of certain environmental controls can lead to impacts to human health and the environment. Given the large quantity of C&D debris generated in the US, the potential for the management and disposal of certain components of C&D debris to impact human health and the environment, and the varied environmental controls required at C&D management facilities, an examination of the potential human health and environmental impacts that may occur is warranted.

1.2 Summary of Previous US EPA Evaluation of C&D Debris Management

The 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act (RCRA) required the US EPA to revise the existing land disposal criteria found in 40 CFR Part 257 for facilities that accepted household hazardous waste and small quantity generator hazardous waste. The US EPA revised criteria for MSW landfills in 1991 (40 CFR Part 258) because a majority of household hazardous wastes and small quantity generator hazardous wastes were disposed of in MSW landfills. Additional criteria for non-hazardous, non-MSW facilities that accepted a portion of these wastes were developed in 1995. A new Subpart B was added to 40 CFR 257 to establish facility standards for non-MSW disposal facilities that receive Conditionally Exempt Small Quantity Generator (CESQG) waste, and C&D debris landfills were included as one of the facility types that may receive CESQG waste (examples of possible CESQG waste included paints, roofing cements, and adhesives). The US EPA commissioned two studies to examine the potential for human health and environmental impacts from C&D debris landfills and gather information regarding the way that C&D debris landfills are regulated at the state level as part of the 40 CFR 257 Subpart B rulemaking to assess whether further restrictions on C&D debris landfills beyond those proposed in the rulemaking were justified.

1.2.1 US EPA Damage Evaluation (1995)

The US EPA commissioned an evaluation of "damage cases" at C&D debris disposal facilities in support of rulemaking related to the CESQG rule (US EPA 1995a). Prior to this examination, C&D debris was a portion of the waste stream that was not widely studied from an environmental impacts perspective and in many cases was largely considered to be inert. The evaluation criteria used in the study included facilities that accepted predominantly C&D debris (with or without CESQG waste), and the definition of damage was limited to cases where the C&D landfill was the only potential or observed contamination source.

The study examined the technical literature, a database of Superfund sites, and information from the state regulatory staff's institutional knowledge to identify damage cases. Two primary resources in the technical literature and responses from 32 states served as the basis for the study's damage case database, which identified 11 damage sites in three states: New York, Virginia, and Wisconsin. A facility was considered to have damage if, based on a review of data and operating records, measured constituent concentrations in groundwater detection wells were above background levels or exceeded corresponding regulatory or health-based standards. The damage case search was inhibited largely by the following factors:

- Information from 32 of 50 states (64%) was evaluated. Some states not contacted were among those with the largest number of C&D landfills (e.g., Louisiana, with 167 C&D landfills as of 1994 [US EPA 1994], was not surveyed).
- Several states did not require groundwater or surface water monitoring, thus the understanding of actual impacts could not be ascertained (e.g., Florida, which had 277 C&D landfills as of 1994 [US EPA 1994], did not require monitoring at the time, thus damage was not evaluated).

The study also included ecological damage as a criterion, defining this type of damage as cases where constituent concentrations measured in surface water exceeded the US EPA's Ambient Water Quality Criteria, which were developed for the protection of aquatic communities. Additionally, the exclusionary criteria used to isolate C&D landfills prohibited the evaluation of several sites that may have had co-disposal of C&D with MSW or that had limited site historical use information available. Note that none of the 11 damage cases had reported damage that fit the ecological damage criteria. Other instances of impacts (e.g., odors) were occasionally noted in site history descriptions but were not examined as a criterion for damage.

All of the 11 reported damage cases had groundwater contamination identified on-site. In nearly all cases, the groundwater impacts were related to the presence of inorganic constituents above maximum contaminant levels (MCLs), including

- manganese (9 of 11 sites); four of the nine sites had measurements that exceeded secondary MCLs (SMCLs) by more than a factor of 100;
- iron (8 of 11 sites); five of the eight sites had measurements that exceeded SMCLs by more than a factor of 100;
- total dissolved solids (TDS, 6 of 11 sites);
- lead (5 of 11 sites);
- magnesium (4 of 11 sites);
- sodium (4 of 11 sites); and
- sulfate (3 of 11 sites).

In most cases, off-site groundwater monitoring data were not available. While a goal of the assessment was to link environmental damages to the design, operation, or location of the landfill, such a connection was not established because of a lack of available or reliable data.

As for surface water impacts, six sites had observed surface water contamination, which primarily consisted of inorganic constituents (iron, zinc, lead, and copper). Two sites had measured sediment contamination in the form of polynuclear aromatic hydrocarbons. None of the sites had reported fish kills or other observable impacts on aquatic life.

The US EPA concluded that impacts to groundwater and surface water had been documented based on the cases that were reviewed. However, they believed that insufficient data existed to require more than the statute required in the revised criteria for facilities that may receive CESQG waste (i.e., groundwater monitoring, corrective action, and location restrictions). The US EPA also concluded that the evaluation of 11 sites out of 1,889 precluded a meaningful, significant data set upon which further decisions could be made.

1.2.2 US EPA C&D Leachate Quality Evaluation and State Regulatory Evaluation (1995)

Data collected on leachate quality and state regulations related to C&D debris management were gathered and evaluated in support of rulemaking related to the CESQG rule in 1995 (US EPA 1995a,b,c). Data for 305 chemical parameters that were sampled at one or more of 21 C&D landfills were compiled. A total of 93 chemical parameters were detected in leachate at least once, and of the 93 detections, 24 had at least one exceedance of a federal drinking water standard or health-based standard. Overall, a total of seven constituents were identified as potentially problematic based on their detection at any landfill where the median value of the detected concentration exceeded the corresponding regulatory limit or health-based standard.

The most frequently detected constituents were iron, lead, manganese, and TDS – more than 70% of all landfills for which data were available had median concentrations of these constituents greater than the corresponding drinking water or health-based standard. The ratios of the median detected concentration of iron and manganese to the corresponding standard were 37:1 and 59:1, respectively, while the ratio for both lead and TDS was approximately 4:1. The report acknowledged that while the data from these landfills indicated the potential for leachate produced at C&D debris landfills to exceed applicable regulatory or health-based standards, the small number of sites (21) compared to the estimated number of sites in the US (1,889) suggests that the data were not a statistically rigorous representation of the population of C&D landfills.

The state regulatory review presented a variety of information regarding the extent of C&D debris facility regulation. The major observations were as follows:

- Groundwater monitoring was required in 29 states for some or all off-site C&D landfills, though the stringency (e.g., frequency required) varied and was often less stringent than 40 CFR Part 258 (24 cases). Off-site C&D landfills are facilities that accept C&D debris from multiple locations (as opposed to an on-site C&D landfill, where construction debris is disposed at the point of generation).
- Corrective action requirements existed for off-site C&D landfills in 22 states..
- Permitting requirements existed in 45 states for off-site C&D landfills.

1.2.3 40 FR 257 Rulemaking

The US EPA acknowledged that requiring non-MSW disposal facilities that receive CESQG waste to comply with all of the same requirements as MSW disposal facilities did not appear necessary because of the apparent lower risk posed by non-MSW facilities (US EPA 1995a). Specifically, the US EPA relied upon the damage case assessment (which reported information from 11 C&D sites that suggested C&D landfills have negatively impacted groundwater quality), the leachate quality evaluation (which suggested leachate from C&D debris can exceed applicable federal drinking water standards, but not at levels or with constituents that were identified as sufficient to warrant additional rulemaking), and information provided by the public during the commenting period of rulemaking to make this determination.

1.3 Project Objectives and Report Outline

The studies conducted as part of CESQG rulemaking in 1994 and 1995 provided US EPA with the state of the practice of C&D debris management at the time, as well as limited data and information related to actual or potential impacts that had occurred at C&D disposal facilities. Since the development of those studies, changes have occurred with respect to C&D debris generation and management, regulation of C&D facilities in the states, as well as the scientific community's understanding of actual or potential risks associated with the management of C&D debris. Some of these changes include:

- Development of more stringent regulations in states for C&D debris management facilities since 1995. This includes expanded requirements for groundwater monitoring, liners and leachate collection systems, and waste prohibitions.
- Expanded practices of C&D debris recycling. Though accurately accounting for specific C&D recycling practices is complex, a US EPA (1998) estimate suggested approximately 20% to 30% of building-related C&D debris was recovered for recycling in 1996, while an updated US EPA (2009) report suggested that a 48% C&D debris recovery rate estimated for eight states may be reasonably applied to the rest of the US. The expanded practice of C&D debris recycling results in two major shifts compared to historical C&D debris management: greater presence of C&D processing and recycling facilities, and a change in the composition of C&D debris delivered to landfills for disposal. Though difficult to quantify, the separation and recycling of bulky C&D

components (e.g., concrete) may result in the removal of C&D components that are not expected to produce a leachate that is harmful to human health and the environment, thus increasing the proportion of discarded C&D materials that could leach elevated concentrations of chemicals of concern.

- Enhanced scientific understanding of C&D debris impacts. Significant research efforts have occurred since the mid-1990s with respect to the characterization of different components of C&D debris, including leaching behavior (e.g., treated wood) and the potential to develop air emissions including reduced sulfur compounds (e.g., from the reduction of sulfate (SO_4^{2-}) contained in gypsum drywall). Additionally, a greater understanding of factors that can contribute to problematic conditions such as fires, as well as approaches to prevent and address fires, has been developed.

In light of the changes that have occurred in the approximately 17 years since the publication of the previous nationwide studies on C&D debris, US EPA Office of Research and Development (ORD) identified C&D debris disposal and management as a priority area for further examination to fill data gaps and further explore C&D facility damage. The specific areas of focus were as follows:

- **Updated Evaluation of State Regulations**, to include a state-by-state assessment of current regulations. The primary focus of the regulatory examination was to assess rules related to the requirements for bottom liner systems, operational conditions such as cover requirements and fire prevention and control, and groundwater monitoring at landfills, and to identify states where C&D debris recycling is a regulated activity.
- **Updated Inventory of Facilities That Primarily Handle C&D Debris**, to include active C&D disposal facilities and C&D processing/recycling facilities.
- **Expanded Criteria for Damage**. The previous investigation by US EPA mainly focused on groundwater impacts and limited data on leachate quality. These criteria were examined further in this evaluation and the criteria were expanded to include air emissions and fires as additional points of concern.
- **Expanded Evaluation of Damage**. The previously conducted damage evaluation included several data gaps. The damage evaluation in this project was expanded to use a three-tier approach. First, developing an inventory of damage sites based solely on discussions with state regulatory personnel. Second, examining large statewide data sets from several states to identify and assess actual or potential environmental impacts. Third, identifying a select number of sites (three) for detailed multi-media examination of damage at the facility level to understand the factors that led to damage.

This report is organized into six sections. Section 1 presents the background on C&D debris management, the project objectives, and the report organization. Section 2 provides a state-by-state regulatory summary and database of active C&D landfills and processing facilities. Section 3 presents an evaluation of six statewide studies related to C&D debris facility damage or compliance and enforcement records. Section 4 presents detailed damage case evaluations for three specific C&D debris sites, two landfills, and one recycling facility. Section 5 presents brief concluding remarks and recommendations for future evaluations. Section 6 presents a listing of references and resources examined in the development of this report.

2. State-by-State Summary of C&D Management

2.1 Overview and Methodology

Currently, no federal rules specific to C&D debris management exist; however, several regulations exist that indirectly impact C&D management facilities (e.g., hazardous waste rules in 40 CFR 261, Subtitle C). A review of C&D debris management regulations in each of the 50 states was conducted to provide appropriate context during the evaluation of data from statewide evaluations (Section 3) as well as the detailed site-specific damage cases (Section 4). Last, the state regulation summary can help facilitate an understanding of potential linkages between C&D debris management and observed human health and environmental impacts.

The regulatory summary was conducted by searching each state environmental agency's websites. The primary focus of the examination focused on rules pertaining to C&D debris disposal facilities, though in some cases rules related to C&D debris recycling facilities were assessed. The regulations were reviewed to gather specific information and understand key differences and similarities among states, including

- whether regulations specific to C&D debris existed;
- bottom liner requirements, with or without leachate collection;
- groundwater monitoring requirements; and
- operational requirements, which may include (but not be limited to) cover soil application requirements and fire prevention and control.

If required, state regulatory agency solid waste personnel were contacted to get clarification on rule interpretation related to one or more of the above-referenced factors. Since laws and regulations are updated from time to time, the information presented for each state in this section should be considered as a snapshot of existing regulations. In some cases, references to ongoing rulemaking are made.

In addition to developing state-by-state regulatory summaries, an inventory of the active C&D debris disposal sites and processing/recycling facilities was developed. Data were sourced using a multi-step process. The primary source of data for the inventory was publicly available databases listed on state environmental regulatory agency websites or lists furnished directly by state regulatory agencies – the database of active C&D landfills was sourced exclusively in this manner. The database of active C&D processors was mostly obtained through state databases and data requests (36 states), while remaining data gaps (9 additional states) were filled by making direct facility contact based on a C&D recycling trade organization website (Construction Materials Recycling Association), and the remainder of the database was populated using data from a trade industry database (Waste Business Journal [WBJ] 2012).

For comparison, the new list of sites was compared to the reported active C&D landfills in the US from the 1994 US EPA report. Data regarding C&D processing facilities were mined from WBJ (2012) by applying exclusionary criteria to eliminate recycling facilities that processed materials other than C&D debris. Specifically, data points for sites that did not identify the waste type processed or that included general recyclables, MSW, industrial waste, sludge, ash, white goods, or any other non-C&D type materials within the description were excluded. Facilities that only processed the following waste types were also excluded from analysis:

- aluminum, copper, red metals, iron, stainless steel, or other metals;
- contaminated soil;
- yard waste; and
- automobile tires.

Finally, the state-by-state evaluation involved developing an inventory of C&D damage sites. The collection and review of each state's regulations was conducted prior to researching potential damage in each state so that appropriate C&D facility classifications and definitions were understood to ensure that reported information on damage was specific to C&D debris facilities. The project team contacted the state solid waste regulatory agency headquarters staff that was identified as most directly involved with C&D debris and/or solid waste permitting or compliance. The regulatory staff were then asked about their awareness of current or recent instances where a permitted C&D debris management facility had impacted the environment or met the definition of damage, which was generally defined as a facility that met one or more of the following criteria:

- Had impacted groundwater, as evidenced through routine monitoring.
- Had recurrent issues with leachate releases or observed leachate containment problems.
- Had odor management or emissions issues, including those with recurring complaints from the surrounding community.
- Had reported fire events.

The evaluation was intended to obtain an inventory of the number of C&D sites in each state that currently or recently had caused damage. Given that this was not a formal survey that was distributed to all states, there are some notable limitations with the data gathered in this effort:

- Several regulatory staff contacted indicated that compliance and enforcement is handled at the regional or district level, so no direct knowledge of problem or damage sites was known at the headquarters level.
- Inquiries relied upon the direct knowledge of the regulatory staff to provide information on sites that had caused damage.
- Specific details or data regarding the sites in general were not gathered, so independent validation or verification of the regulatory staff's assessment of damage was not made.
- The nature of the question of damage (even in light of the clarifying remarks above) is somewhat subjective, thus a response of "yes" to damage from one respondent could also be a response of "no" from another respondent, and vice versa.

In a limited number of instances the project team utilized other publicly available resources to identify damage sites in different states, which included public meeting notices, news media archives, and environmental monitoring reports. Only facilities that met the criteria described previously were included in the inventory.

2.2 State Regulatory Evaluation of C&D Debris Management

2.2.1 Alabama

The solid waste regulating authority is the Alabama Department of Environmental Management (ADEM). The rules for the Land Division - Solid Waste Program are provided within ADEM Administrative Code Division 13. Construction/demolition waste is defined to include non-putrescible and non-hazardous solid waste, specifically: waste building materials, packaging, and rubble resulting from construction, remodeling, repair, or demolition operations on houses, commercial buildings, and other structures. Such wastes include, but are not limited to, masonry materials, sheet rock, roofing waste, insulation (not including asbestos), scrap metal, and wood products.

Construction/demolition-inert landfill units (C/DLF) can receive construction/demolition waste, rubbish, water treatment (alum) sludge, or foundry waste meeting Rule 335-13-4-.26(3). Industrial landfill units (ILF) receive industrial solid waste and may also receive construction/demolition waste and or/rubbish.

Materials such as asphalt, clean concrete, and green waste are excluded from the definition of C&D waste.

Bottom liners are not required for C/DLFs or ILFs as long as liquid waste is not accepted. Groundwater monitoring is not required for C/DLFs unless industrial waste or other prohibited materials have been accepted. Weekly soil cover application is required for C/DLFs.

2.2.2 Alaska

The Alaska Department of Environmental Conservation regulates solid waste through the Alaska Administrative Code; Title 18 Environmental Conservation, Chapter 60 Solid Waste Management. Many C&D-type materials are exempt from the requirements of the solid waste rules unless they are mixed with non-exempt waste or there is an identified threat to health or the environment. Such excluded materials include: land clearing waste, including excavated dirt, rock, soil, butt ends, and stumps; tree limbs and other foliage or woody debris, sometimes referred to as "slash" in a timber harvest area; bricks, mortar, and Portland cement type concrete, including reinforcing steel that cannot be easily removed; crumb rubber used in asphalt paving; and crushed glass.

For C&D material that must be landfilled, there are provisions for disposal within municipal landfills, non-municipal landfills, or inert waste monofills. Inert waste monofills were the most relevant type of facility to investigate regarding C&D waste management in Alaska because these facilities primarily accept C&D and non-ash waste. Bottom liners are not required and groundwater monitoring is conditional at inert monofills. Groundwater monitoring is not required for an inert monofill with a volume of less than 1,000 cubic yards (yd^3), or located within an area that receives 25 in. or less of total precipitation each year. Unless there has been a non-inert load of waste placed, there is unexplained contamination in nearby wells or there is evidence of a spill, groundwater monitoring is not required. Cover requirements are determined on a case-by-case basis. The owner or operator of an inert waste monofill that accepts combustible inert waste must maintain fire control equipment to extinguish any fires that may occur.

2.2.3 Arizona

The Arizona Department of Environmental Quality is the state solid waste regulatory authority. The state has not established rules specific to C&D debris landfills. Construction debris and demolition debris are defined within the state statutes. Construction debris means solid waste derived from the construction, repair, or remodeling of buildings or other structures, and demolition debris means solid waste derived from the demolition of buildings or other structures. Within the Arizona Administrative Code Title 18: Environmental Quality, Chapter 13: Department of Environmental Quality- Solid Waste Management, both C&D landfills as well as private landfills fall under the definition of non-municipal solid waste landfills (non-MSWLFs). C&D landfills only accept solid waste derived from constructing, repairing, or remodeling of buildings or other structures or demolishing buildings or other structures. Private landfills accept only permitted wastes generated on-site. There are no specific bottom liner requirements, however, non-MSWLFs are required to use best available demonstrated control technology and may be subject to groundwater monitoring as a condition of an Aquifer Protection Permit (APP). Most APPs require 6 in. of soil as daily cover. Some landfills are also permitted to use alternative daily cover.

2.2.4 Arkansas

The Arkansas Pollution Control and Ecology Commission created Regulation No. 22: Solid Waste Management Rules, which are administered by the Arkansas Department of Environmental Quality (ADEQ). C&D waste is defined as: any and all material and debris that might result from the construction or demolition of any building or other manmade structure including but not limited to single and multifamily dwellings, commercial buildings, road and highway construction and repair, remodeling and additions to existing structures, and roofing. Materials may include (but are not limited to) dimensional

lumber, roofing materials, bricks, concrete blocks, siding, gypsum (drywall), masonry, metal, cardboard, concrete with and without rebar, fill materials (including earth, gravel, and stone), glass, and any other material that may be used in any construction project or may be salvaged from any demolition project.

C&D waste falls under a Class 4 waste designation, which includes nonhazardous, bulky, inert, non-putrescible solid wastes that do not degrade, or degrade very slowly. Class 4 wastes also include appliances, furniture, stumps, limbs, and other bulky wastes that are not normally collected with other household, commercial, or industrial waste. Liners for Class 4 landfills are conditionally required. When landfills are sited in a location that provides permeability $\leq 1\times10^{-5}$ cm/sec and all other standards are met, a liner is not required. Otherwise, an 18 in. thick compacted clay liner (at a minimum) with a hydraulic conductivity no greater than 1×10^{-5} cm/sec is required.

Class 4 landfills are exempt from groundwater monitoring unless the Director of ADEQ determines monitoring is required to confirm groundwater standards are met. At a minimum, weekly cover with 6 in. of earthen materials must be applied to control disease vectors, fires, odors, blowing litter, and scavenging and to limit the generation of leachate. Daily spreading and compaction of the waste shall be performed to minimize void space and reduce the potential for disease vectors and fires. Control of explosive gases through a methane (CH_4) monitoring program may be required if the Director determines that waste quantities and characteristics of explosive gas standards are exceeded.

2.2.5 California

The California Environmental Protection Agency includes the Waste Permitting, Compliance and Mitigation Division, which is within the Department of Resources Recycling and Recovery (CalRecycle), the C&D waste regulatory oversight body. Compliance and enforcement of facilities is generally handled at the local level by local enforcement agencies (LEAs). Within the California Code of Regulations Title 14 Natural Resources and Title 27 Environmental Protection, there is language that pertains to C&D waste disposal and recycling. C&D waste could fit under both definitions of C&D Waste and Type A inerts simultaneously (Type A inerts are effectively a subset of C&D waste). C&D Waste includes waste building materials, packaging, and rubble resulting from construction, remodeling, repair and demolition operations on pavements, houses, commercial buildings, and other structures. Type A inert debris includes concrete (including fiberglass or steel reinforcing bar embedded in the concrete), fully cured asphalt, glass, fiberglass, asphalt or fiberglass roofing shingles, brick, slag, ceramics, plaster, clay and clay products. Type A inert debris is waste that does not contain soluble pollutants at concentrations in excess of water quality objectives and has not been treated in order to reduce such pollutants.

C&D waste may be disposed of at C&D debris, inert debris (CDI), or MSW disposal facilities; inert waste can also be disposed of in inert waste disposal landfills. Typically, CDI facilities are fully permitted solid waste facilities and fall under Class III non-hazardous waste facility regulations; Type A inert debris disposal facilities are required to obtain a registration permit (which is easier to obtain than fully permitted status) prior to beginning operations. CDI and inert debris processing facilities are regulated depending on the waste type being processed and at the daily waste throughput. For example, CDI processors can be small (<25 tons per day [tpd]), medium (25 – 175 tpd) or large (>175 tpd) volume facilities and thus respectively must submit or obtain the following paperwork: Local Enforcement Agency notification, registration, or full solid waste facility permit. The state's Regional Water Boards have final authority over the extent to which all facilities are permitted. There are also inert waste engineered fill operations, which are different from CDI disposal sites because the material is used to create a dense mass that can support structural loading and may be used for recreational, agriculture, roads, buildings or other approved purposes.

In general, liners are conditional for Class III disposal facilities; if site characteristics do not ensure protection of the quality of ground water or surface water, Class III landfills are required to have a single

clay liner with hydraulic conductivity of 1×10^{-6} cm/sec or less. Leachate collection is required if a facility has a liner or accepts sewage or water treatment sludge. Water quality monitoring is required and gas monitoring and control are required to keep CH_4 and trace gases from migrating off site or causing any adverse exposure. A minimum of 6 in. of compacted earthen material is to be applied at the end of each operating day to control vectors, fires, odors, blowing litter, and scavenging. Earthen material may include contaminated soil and soil with contaminants other than petroleum hydrocarbons that has been approved for use as daily cover. As previously noted, the Regional Water Boards have final regulatory jurisdiction and may require more stringent facility operational practices on a case-by-case basis.

2.2.6 Colorado

In Colorado, the Department of Public Health and Environment, Hazardous Materials and Waste Management Division regulates solid waste facilities. The Regulations Pertaining to Solid Waste Sites and Facilities are provided in 6 Code of Colorado Regulations 1007-2 Part 1. The definitions of both inert waste and C&D debris describe common C&D wastes. Inert material is defined as non-water soluble and non-putrescible solids. The term includes materials such as earth, sand, gravel rock, concrete, masonry, asphalt paving fragments, and other inert solids. C&D debris is waste generated from construction, remodeling, repairs, or demolition of buildings, pavements, and other structures which includes but is not limited to, lumber, bricks, carpets, ceramics, sheetrock, metals, drywall, window glass, metal and plastic piping, paint, and any other non-hazardous materials resulting from C&D operations. There are inert waste landfills that accept only inert waste but there are currently no C&D waste-only landfills, as standard practice in the state is for C&D waste to be disposed of at MSWLFs. Debris and ash from fires within the state are classified as "special waste" and are disposed at MSWLFs after being wrapped in 6-mil thick plastic sheeting. There is a section reserved within the rules to specifically address C&D disposal facilities and there are ongoing discussions with the mining industry to develop an approach to regulate C&D disposal facilities.

At present, independent C&D facilities would be regulated under the rule sections that generally address disposal landfill sites and facilities. Design and operational requirements include a liner comprised of natural lithology (compacted), a soil liner, a composite liner, or an alternative design; an accompanying leachate collection system designed to maintain less than 1 ft of leachate head over the barrier layer, promoting transport of leachate from the most distant point of the leachate collection system to the leachate removal system in less than 12 months; and groundwater monitoring. The owners or operators of all solid waste disposal sites and facilities that may generate explosive gases must also monitor for explosive gases and implement a routine monitoring program. The type and frequency of monitoring will vary depending on the site but if elevated levels are measured, a remediation plan must be created and followed. Additionally, the owners or operators of all landfills must cover disposed solid waste with 6 in. of earthen material at the end of each operating day, or at more frequent intervals if necessary to control disease vectors, fires, odors, blowing litter, and scavenging.

2.2.7 Connecticut

The State of Connecticut Department of Environmental Protection is the regulating body for solid waste. Title 22a Chapters 208 & 209 provide the rules for solid waste facilities. C&D waste is defined as waste building materials or packaging resulting from construction, remodeling, repair, or demolition operations on houses, commercial buildings, and other structures, excluding asbestos, clean fill, or solid waste containing greater than de minimis quantities of radioactive, liquid, or hazardous waste. The definition of bulky waste includes land clearing debris and waste resulting directly from demolition activities other than clean fill.

Many of the landfills accepting C&D (bulky waste landfills) in Connecticut have limited capacity or are closed, and therefore a majority of the C&D waste generated in Connecticut is first size-reduced and then transported out of state for disposal. There are no liner or leachate collection requirements for bulky waste

disposal sites in Connecticut, but groundwater monitoring and daily cover are required. There are also provisions listing fire protection measures, including immediate notification of the Department when there is smoldering, smoking, or burning on site; contacting the fire department; continuing firefighting until all smoldering, smoking, and burning has ceased; closing the facility if required; not conducting disposal activities in the immediate vicinity of smoldering, smoking, or burning; and fixing any structural damage caused by fire.

2.2.8 Delaware

The Department of Natural Resources and Environmental Control is the regulatory authority for solid waste. The regulations applicable to C&D waste are within the Delaware Administrative Code Title 7 Natural Resources and Environmental Control, 1301 Regulations Governing Solid Waste. C&D waste is not explicitly defined within the Delaware solid waste rules but C&D materials can be classified as dry and industrial wastes. Dry waste means wastes including, but not limited to, plastics, rubber, lumber, trees, stumps, vegetative matter, asphalt pavement, asphaltic products incidental to construction/ demolition debris, or other materials that have reduced potential for environmental degradation and leachate production. Industrial waste means any waterborne liquid, gaseous, solid, or other waste substance or a combination thereof resulting from any process of industry, manufacturing, trade or business, or from the development of any agricultural or natural resource.

Landfills classified as industrial can accept both industrial and dry wastes and thus C&D-type wastes. There is one industrial landfill in Delaware that accepts mostly C&D waste. Delaware requires bottom liners for industrial landfills; depending on site characteristics, the liner may be a composite, natural or double liner. Unless otherwise approved, the bottom of the liner (second liner for a double liner) must be at least 5 ft above the seasonal high groundwater table. A leachate collection system is required along with a leachate treatment and disposal system, and a leachate monitoring system. The leachate collection system must be designed to prevent the leachate head on the liner from exceeding 1 ft. Gas control systems must be installed at industrial landfills where the materials landfilled would be expected to produce gas, and a sufficient number of gas monitoring wells shall be installed to evaluate gas production rates in the landfill. Groundwater monitoring is required. The Department specifies the thickness and frequency of approved material for landfill cover; typically cover is applied at least once every 2 weeks.

2.2.9 Florida

The Florida Department of Environmental Protection (FDEP) is the regulatory authority for solid waste management. C&D debris and C&D Disposal and Recycling regulations are located within the Florida Administrative Code, Chapter 62-701.730. Florida defines C&D debris as follows: discarded materials generally considered to be non-water soluble and non-hazardous in nature, including but not limited to steel, glass, brick, concrete, asphalt material, pipe, gypsum wallboard, and lumber, from the construction or destruction of a structure as part of a construction or demolition project or from the renovation of a structure, including such debris from construction of structures at a site remote from the construction or demolition project site. The term includes rocks, soils, tree remains, trees, and other vegetative matter that normally results from land clearing or land development operations for a construction project; clean cardboard, paper, plastic, wood, and metal scraps from a construction project; yard trash and unpainted, non-treated wood scraps from sources other than construction or demolition projects; scrap from manufacturing facilities that is the type of material generally used in construction projects and that would meet the definition of construction and demolition debris if it were generated as part of a construction or demolition project, including debris from the construction of manufactured homes and scrap shingles, wallboard, siding concrete, and similar materials from industrial or commercial facilities and de minimis amounts of other non-hazardous wastes that are generated at construction or demolition projects, provided such amounts are consistent with best management practices of the construction and demolition industries. Mixing of C&D debris with other types of solid waste will cause it to be classified as other than C&D debris.

C&D debris can also fall under the definition of Class III waste and therefore be disposed of in a Class III landfill that also accepts yard trash, processed tires, asbestos, carpet, cardboard, paper, glass, plastic, furniture other than appliances, or other materials approved by the FDEP that are not expected to produce leachate that poses a threat to public health or the environment. Materials defined as Class III waste but are not C&D debris cannot be disposed of in a C&D debris landfill. Liner and leachate collection systems are not required for C&D debris disposal facilities unless the FDEP determines that based upon the types of waste received, methods for controlling the types of waste disposed of, the proximity of ground water and surface water, and the results of the hydrogeological and geotechnical investigations that operation of the facility is reasonably expected to result in violations of ground water standards and criteria otherwise. However, recently promulgated rules in Florida require Class III landfills to be constructed with a liner and leachate collection system unless the permit applicant can demonstrate that a liner and leachate collection system are not needed. Groundwater monitoring is required at C&D debris disposal facilities on a semiannual basis. There are no minimum operational soil cover requirements. Unless a facility's operational plan states otherwise, the working face and internal slopes of disposal units should be no greater than 3 ft horizontal run to 1 ft vertical rise so that fires can be controlled.

2.2.10 Georgia

The Georgia Department of Natural Resources, Environmental Protection Division is the solid waste authority for Georgia. The Solid Waste Management rules are provided within Chapter 391-3-4. Construction/Demolition waste in Georgia is disposed of within C&D landfills. The specific definition of C&D waste is: waste building materials and rubble resulting from construction, remodeling, repair, and demolition operations on pavements, houses, commercial buildings, and other structures. Such wastes include, but are not limited to asbestos containing waste, wood, bricks, metal, concrete, wall board, paper, cardboard, inert waste landfill material, and other non-putrescible wastes that have a low potential for groundwater contamination.

Unless a variance is granted by the Department, liner, leachate, and daily cover requirements, as set forth for MSWLFs, apply to C&D landfills. These provisions include a liner with leachate collection that must ensure that the concentration values of MCLs of listed chemicals are not exceeded in the uppermost aquifer at the relevant point of compliance. Depending on the site location, liner requirements may be more stringent if the site is located within an area of higher pollution susceptibility or a significant groundwater recharge area. Disposed solid waste shall be covered with 6 in. of earthen material at the end of each operating day at a minimum, to control disease vectors, fires, odors, blowing litter, and scavenging.

Groundwater monitoring is required at C&D landfills and the monitoring system should provide sufficient data on the background quality of the uppermost aquifer along with the quality of groundwater passing the relevant point of compliance specified by the Director. There are also provisions for controlling explosive gases, which include a CH_4 monitoring program with quarterly monitoring and the steps to take when CH_4 concentration limits are exceeded. Facilities are also to be designed to prevent and minimize the potential for fire or explosion, and a minimum supply of 1 day of cover material must be maintained within 200 ft of the working face for firefighting purposes unless other acceptable means have been approved.

Georgia's regulations also have provisions for inert waste landfills, defined as disposal facilities accepting only wastes that will not or are not likely to cause production of leachate of environmental concern. Such wastes are limited to earth and earth-like products, concrete, cured asphalt, rock, bricks, yard trimmings, stumps, limbs, and leaves. This definition excludes industrial and demolition waste not specifically listed above. Inert waste landfills, because they are more restrictive in the types of materials accepted, only require a permit-by-rule (PBR). Under the PBR the facility is required to have 1 ft of cover placed over exposed waste at least monthly, and soil should be stockpiled for use against fires. Liners, leachate

collection, and groundwater monitoring are not discussed within the regulations relating to inert waste landfills. The Environmental Protection Division is in the process of recommending updates to the inert rules requiring permits; the proposal is currently being reviewed by the Board of Natural Resources.

2.2.11 Hawaii

The Department of Health is the regulatory body for solid waste management facilities in Hawaii. Regulations on solid waste management facilities, including those that accept C&D waste, are provided in the Hawaii Administrative Rules Title 11, Chapter 58.1. C&D waste is disposed of within C&D solid waste landfills. C&D waste includes: solid waste resulting from the construction, repair, demolition, or razing of buildings, of roads, and other structures and includes land clearing debris from the clearing of land for construction. C&D wastes typically consist of concrete, hollow tile, bituminous concrete, asphaltic pavement, wood, glass, masonry, roofing, siding, and plaster, alone or in combinations.

C&D solid waste landfills are required to have a liner system with a 2-ft thick soil layer (minimum) with a maximum permeability of 1×10^{-5} cm/sec or an approved alternative design. Leachate collection is not specifically noted in the rules; however a leachate management plan is required. Groundwater monitoring is required and interim cover requirements are specified. More stringent facility design and operational requirements may be determined on a case-by-case basis.

2.2.12 Idaho

The Department of Environmental Quality and the local health districts share responsibility for regulating solid waste facilities. C&D wastes are not specifically defined within the Idaho Administrative Code 58.01.06 Solid Waste Management Rules. Inert waste is defined as noncombustible, nonhazardous, and non-putrescible solid wastes that are likely to retain their physical and chemical structure and have a de minimis potential to generate leachate under expected conditions of disposal, which includes resistance to biological attack. Inert waste includes, but is not limited to, rock, concrete, cured asphaltic concrete, masonry block, brick, gravel, dirt, inert coal combustion byproducts, inert precipitated calcium carbonate, and inert component mixtures of wood or mill yard debris. Inert waste is exempt from the solid waste rules. C&D type wastes that do not fit the description of an inert waste are regulated as solid waste and can be placed within non-MSWLFs.

Non-MSWLFs are classified in tiers and can accept different quantities and characteristics of waste. With respect to accepting C&D waste, Tier I facilities are typically reserved for use in small (less than 200 yd^3), one-time building demolition projects. Tier I facilities have minimal design and operational requirements. The majority of C&D waste disposed in Idaho is placed within Tier II facilities. These sites are not required to install groundwater monitoring wells, liners, or leachate collection systems. Facilities classified by the Department as a Tier II must not accept CESQG hazardous waste, waste with high pathogenic potential, or waste in high volumes that may form toxic leachate or gas or harm the environment. The total disposal capacity of Tier II facilities must be greater than 2,000 yd^3. C&D waste that cannot be placed within a Tier II landfill because of prohibitive quantities or material that may contain CESQG hazardous waste can be accepted into Tier III facilities. Tier III facilities are regulated similarly to MSWLFs and are required to have groundwater monitoring, liners, leachate collection systems, and air contaminant control systems.

2.2.13 Illinois

The Pollution Control Board is the rule promulgating authority, and the Illinois EPA is the enforcing authority for solid waste in Illinois. Title 35 of the Illinois Administrative Code, Subtitle G: Waste Disposal, Chapter I: Pollution Control Board, Subchapter i: Solid Waste Part and Special Waste Hauling Part, acknowledges that C&D landfills do not exist in Illinois. There are numerous clean construction and demolition debris (CCDD) fill operations that accept uncontaminated broken concrete without protruding

metal bars, bricks, rock, stone, reclaimed asphalt pavement, or soil generated from C&D activities. These fill operations are not recognized as disposal sites because the fill materials are considered to be used beneficially. Subtitle J: Clean Construction or Demolition Debris, Chapter I: Pollution Control Board, Part 1100 details the requirements for CCDD Fill Operations, which does not require liners, leachate collection, or groundwater monitoring. A fill operation cannot be located in a setback zone of a potable water supply well, and there should be surface water controls. Fill cannot be applied above the highest grade permitted at the facility, and 1 ft of uncontaminated soil is to be applied at closure.

The Illinois EPA has recognized that there is the potential for CCDD fill operations to have environmental impacts. However, the update of the regulations for CCDD fill operations (which became effective on 27 August 2012), promulgated by the Pollution Control Board, does not require groundwater monitoring but does include new requirements to evaluate potential waste materials to assess the potential for groundwater impacts.

Illinois defines inert waste as any solid waste that will not decompose biologically, burn, serve as food for vectors, form a gas, cause an odor, or form a contaminated leachate. Inert waste may include, but is not limited to, bricks, masonry, and concrete. Although inert waste landfills have provisions written into the regulations that address several types of C&D waste, there have not been any facilities permitted under the inert waste landfill classification. Therefore, C&D wastes that are not suitable for a CCDD fill operation are regulated as solid waste and are disposed of at an MSW landfill.

2.2.14 Indiana

The Indiana Department of Environmental Management, Solid Waste Management Board is the solid waste regulating authority. Indiana Administrative Code Title 329 Articles 10 & 11 addresses C&D debris management. Construction/demolition waste is defined as solid waste resulting from the construction, remodeling, repair, or demolition of structures. Wastes that may be included are scrap lumber, bricks, concrete, stone, glass, wallboard, roofing, plumbing fixtures, wiring, and non-asbestos insulation. The following uncontaminated C&D type materials are excluded from regulation: rocks, bricks, concrete, road demolition waste, and dirt.

Construction/demolition sites require at minimum a soil barrier with a minimum thickness of 3 ft between the solid waste and the aquifer, and a hydraulic conductivity $\leq 1\times10^{-6}$ cm/sec. Leachate collection and groundwater monitoring are not required and no less than 6 in. of cover must be applied weekly.

2.2.15 Iowa

The Iowa Department of Natural Resources is the solid waste regulatory authority. C&D management is addressed within Iowa Administrative Rules, Chapter 567-100 & 114. Construction and demolition waste is defined as waste building materials including wood, metals and rubble (stone, brick, or similar inorganic material) that result from construction or demolition of structures. Tree waste is included in the definition of C&D. Although the term rubbish includes several C&D type materials such as glass and wood, construction and demolition waste is the terminology used consistently throughout Iowa's regulations, and construction and demolition waste disposal sites are sanitary landfills that accept only construction and demolition wastes.

The construction and demolition waste disposal sites require both liners and leachate collection systems. The minimum liner requirement is a soil liner consisting of at least 4 ft of re-compacted soil with a coefficient of permeability 1×10^{-7} cm/sec or less. A composite liner system consisting of an upper component with a minimum 30 mil flexible membrane liner (60 mil if it is high density polyethylene [HDPE]), and a lower component consisting of at least a 2 ft layer of compacted soil with a coefficient of permeability of 1×10^{-7} cm/sec. The leachate collection, storage, and treatment and disposal system shall be designed to protect the soils, surface water, and groundwater from leachate contamination. This system

shall be designed to operate during the active life of the site and during the post-closure period. Groundwater monitoring is required, and waste shall be covered with a minimum of 1 ft of earth at least once every 7 days of operation.

2.2.16 Kansas

The Department of Health and Environment is the regulatory authority for solid waste in Kansas. The Kansas Administrative Regulations, Article 29 - Solid Waste Management, define C&D waste as including bricks, concrete and other masonry materials, roofing materials, soil, rock, wood, wood products, wall or floor coverings, plaster, drywall, plumbing fixtures, electrical wiring, electrical components containing no hazardous materials, non-asbestos insulation, and construction-related packaging. C&D landfills are used exclusively for the disposal of C&D wastes and do not include sites used exclusively for the disposal of clean rubble; clean rubble and uncontaminated soil are essentially unregulated. If a city or county has established its own C&D facility standards that are more stringent than the state requirements, enforcement authority may be given to the local agency by the Department.

C&D landfills are not required to have a liner or leachate collection; however there are specifications for a minimal vertical distance of 5 ft from the bottom of waste to the highest predicted groundwater level with the separation distance to be provided by either an in-situ, geologic, or alternative material. Additionally, C&D contact water, liquid consisting primarily of precipitation that has been in contact with the C&D waste, including all runoff from the active area of the C&D landfill and all liquid derived from the C&D waste, must meet control and management requirements. The operator shall apply cover material over every 2,000 tons of waste disposed, with a minimum of 1 ft of soil to limit air intrusion and control the risk of fire, control litter and vectors. Cover shall be applied at least once every 120 days; however no facility shall be required to apply cover more often than once a week.

Site owners and operators must make arrangements for fire protection services if a fire protection district or other public fire protection service is available. If there is a fire at the site, the operator must initiate and continue the use of appropriate firefighting methods until all smoldering, smoking, and burning cease; notify the department within 1 business day and submit a written report to the department within 1 week; and upon completion of firefighting activities, cover and regrade each disrupted finished grade, covered surface, or completed surface.

2.2.17 Kentucky

The Energy and Environment Cabinet, Department for Environmental Protection is the regulating authority for solid waste in Kentucky. C/D waste is defined in Kentucky Administrative Regulations, Title 401 Chapters 47 Solid Waste Facilities & 48 Standards for Solid Waste Facilities as waste resulting from the construction, remodeling, repair, and demolition of structures and roads, and for the disposal of uncontaminated solid waste consisting of vegetation resulting from land clearing and grubbing, utility line maintenance, and seasonal and storm related cleanup. Construction material is also defined and means nonhazardous non-soluble material, including but not limited to steel, concrete, brick, asphalt roofing material, or lumber from a construction or demolition project. Construction/demolition debris is disposed of within construction/demolition debris landfills, and construction materials can be disposed of within inert landfills which also accept inert, non-soluble and non-putrescible solid waste, certain industrial or special waste, and other waste material with specific approval from the cabinet.

C/D landfill technical requirements vary depending on the size of the facility. Landfills with an area greater than 1 acre must have a liner system. A bottom soil liner of a minimum thickness of 1 ft with a maximum hydraulic conductivity of 1×10^{-7} cm/sec or its equivalent is required. The liner must cover the bottom and sidewalls of the facility. If a facility restricts the waste to C/D debris, non-putrescible wastes, and wastes that are not likely to leach, the liner design requirement may be modified to a minimum of 2 ft of re-compacted soil. The leachate collection system shall be capable of removing leachate from the top

surface of the low permeability soil component, and conveying it to a collection point and meet all specified design requirements. Groundwater monitoring is required. The owner or operator shall apply a 1 ft soil cover such that the area of exposed waste does not exceed 10,000 ft^2 and all exposed wastes are to be covered at least once each week to reduce fire hazards, prevent an unsightly appearance, and eliminate disease vectors. A fire safety and response plan must also be developed and maintained. The plan shall identify measures that shall reduce the risk of fire at the facility, identify the equipment and procedures to respond to a fire, and supplement the local fire department's capabilities.

C/D debris landfills of 1 acre or less can be registered as PBR facilities. Liners and leachate collection are conditionally required, and groundwater monitoring is not required. The rules pertaining to C/D landfills less than 1 acre in size are in the process of being updated, and potential changes include a required liner and leachate collection and a formal engineered site plan.

2.2.18 Louisiana

The Louisiana Department of Environmental Quality is the solid waste regulating authority. Within the Environmental Regulatory Code (Louisiana Administrative Code (LAC) Title 33) Part VII Solid Waste, C/D debris is defined as nonhazardous waste generally considered not water-soluble that is produced in the process of construction, remodeling, repair, renovation, or demolition of structures, including buildings of all types (both residential and nonresidential). Solid waste not included within this definition includes regulated asbestos-containing material as defined in LAC 33:III.5151.B, white goods, and creosote-treated lumber. C/D debris is accepted by Type III Facilities, which are facilities used for disposing or processing of C/D debris or wood waste, composting organic waste to produce a usable material, or separating recyclable wastes. The following solid wastes are not subject to the permitting requirements or processing or disposal standards of the solid waste regulations: brick, stone, reinforced and unreinforced concrete, and asphaltic roadbeds. C/D disposal facilities are not subject to permitting if they receive only on-site generated debris.

A liner and leachate collection system and groundwater monitoring are not specified within the regulations for Type III facilities. However, the facility must be located in an area with natural or designed soils of low permeability to protect groundwater. Wastes shall be covered with silty clays applied in a layer a minimum of 1 ft thick, and all wastes shall be covered within 30 days of disposal.

2.2.19 Maine

The Maine Department of Environmental Protection Bureau of Remediation and Waste Management is the state regulating authority for solid waste. The Maine Solid Waste Management Rules Chapters 400, 401, 405, 409 are applicable to C&D waste management. C/D debris is defined as solid waste resulting from construction, remodeling, repair, and demolition of structures. It includes but is not limited to: building materials, discarded furniture, asphalt, wall board, pipes, and metal conduits. It excludes partially filled containers of glues, tars, solvents, resins, paints, or caulking compounds; friable asbestos; and other special wastes. Inert fill is also defined within the rules as clean soil material, rock, bricks, crushed clean glass or porcelain, and cured concrete. Inert waste is exempt from the requirements set forth within the Solid Waste Management rules.

C/D debris landfills less than 6 acres in size and qualifying under Section 7 of Chapter 401 are not required to have a bottom liner system. A leachate management system may be required if site natural soils do not allow adequate leachate infiltration. The active area within the solid waste boundary must be covered with soil material or other approved cover so that no more than 0.5 acres remains uncovered at any time. Groundwater monitoring is not required but surface water quality monitoring is required.

For other C/D debris landfills not qualifying for licensing under Section 7 of Chapter 401, a liner and leachate collection system is required. The liner must be a composite consisting of a geomembrane and a

barrier soil layer. The geomembrane must have a nominal thickness of 60 mil. The barrier soil layer must consist of a minimum of 2 ft of re-compacted clay or well graded till containing a minimum of 35 % fines. A geosynthetic clay liner (GCL) may substitute for up to 1 ft of the barrier soil layer component of the liner system. Each liner system component must have a hydraulic conductivity $\leq 1\times10^{-7}$ cm/sec. A leachate collection system must be incorporated in the design above the liner system, and a leak detection system and leachate storage system are required as well. Groundwater monitoring is required, and facilities must also monitor gas collection or venting systems and have a quarterly CH_4 gas monitoring program to verify the concentration of explosive gases generated by the landfill. The gas management rules are in the process of being updated. Daily cover is not required, however, depending on the types of materials accepted by a facility, application of cover material may be required or recommended in a facility's permit.

Fire protection is described similarly for small (<6 acres) and larger C/D debris landfills. The requirements are to arrange with a nearby fire department to provide emergency service, possess sufficient on-site equipment for minor fires, to maintain a soil stockpile sufficient to suppress small fires, and to observe the current applicable rules of the State of Maine Bureau of Forestry, Department of Conservation.

2.2.20 Maryland

The Department of the Environment is the regulating authority for solid waste in Maryland. The Code of Maryland Regulations Title 26 Department of Environment, Subtitle 04 Regulation of Waste Supply, Sewage Disposal and Solid Waste, addresses C&D waste. Maryland has various types of sanitary landfills that are regulated. Rubble landfills are one such type of sanitary landfill that accepts C&D wastes. In general, the types of materials accepted at rubble landfills are land clearing debris, demolition debris, construction debris, tires, asbestos, household appliances and white goods, processed debris, and other materials. Acceptable demolition debris may include debris associated with the razing of buildings, roads, bridges, and other structures includes structural steel, concrete, bricks (excluding refractory type), lumber, plaster and plasterboard, insulation material, cement, shingles and roofing material, floor and wall tile, asphalt, pipes and wires, and other items physically attached to the structure, including appliances if they have been or will be compacted to their smallest practical volume. Acceptable construction debris may include structural building materials including cement, concrete, bricks (excluding refractory type), lumber, plaster and plasterboard, insulation, shingles, floor, wall and ceiling tile, pipes, glass, wires, carpet, wallpaper, roofing, felt, or other structural fabrics. Paper or cardboard packaging, spacing, or building materials, provided that they do not exceed 10% by volume of the waste, may be accepted at rubble landfills. Paint containers, caulk containers, or glaze containers may be acceptable, provided that they are empty and any residual material is dried before acceptance at the rubble fill, and further provided that this waste category does not exceed 1% by volume of the waste accepted at the rubble landfill. County governments can specify in their 10-year solid waste master plans what a rubble landfill within their jurisdiction can accept. When permitting is developed by the state for a facility, the applicant's requests, what the County allows, and the state's assessment of the facility's design ability and meeting standards determines the specific waste materials that can be accepted into rubble landfills in Maryland.

A bottom liner, leachate system, and groundwater monitoring are required. The liner may be constructed of natural earthen materials excavated from the site or imported from another location, or it may be constructed of a synthetic or manufactured membrane material. The liner must be constructed with a minimum thickness of 1 ft of clay or other natural material having an in-place permeability $\leq 1\times10^{-7}$ cm/sec, or one or more unreinforced synthetic membranes with a combined minimum thickness of 50 mil or a single reinforced synthetic membrane with a minimum thickness of 30 mil which has a permeability $\leq 1\times10^{-10}$ cm/sec. The liner shall be installed over a subbase with a minimum thickness of 2 ft and having a permeability $\leq 1\times10^{-5}$ cm/sec. Although clay liners may meet state requirements, in practice all active rubble fills employ geomembranes as the bottom liner material. An engineered leachate

collection and removal system must be designed, constructed, operated, and maintained to collect and remove leachate from the landfill and operated to ensure that the depth of leachate over the liner does not exceed 1 ft. At least every 3 days, 6 in. of clean earth shall be placed over all exposed rubble waste. There are no specific provisions for fire prevention and control in the rules.

2.2.21 Massachusetts

Massachusetts Department of Environmental Protection is the regulating authority for solid waste. The 310 Code of Massachusetts Regulations 16.00 and 19.000 Solid Waste Management discusses solid waste management rules. Within these rules, C&D waste is defined as the waste building materials and rubble resulting from the construction, remodeling, repair or demolition of buildings, pavements, roads or other structures. C&D waste includes, but is not limited to, concrete, bricks, lumber, masonry, road paving materials, rebar and plaster. The state currently has a disposal ban for many materials that fall within the definition of C&D debris (asphalt pavement, brick, concrete, metal, wood, and clean gypsum wallboard), therefore these materials are first processed at a recycling facility before they can be disposed. At present there are no active C&D only disposal sites. Closed facilities may have liners and leachate collection, depending on when the facilities were constructed; groundwater monitoring is required.

There are regulations for C&D waste processing facilities including requiring handling to occur indoors, appropriate materials to be stored and covered on an impervious surface, and any water that comes in contact with the recyclable materials to be properly handled.

2.2.22 Michigan

The Resource Management Division of the Department of Environmental Quality is the solid waste regulating authority in Michigan. The Waste and Hazardous Materials Division Part 115 regulations define C&D waste as waste building materials, packaging, and rubble that results from construction, remodeling, repair, and demolition operations on houses, commercial or industrial buildings, and other structures. C&D waste includes trees and stumps that are more than 4 ft in length and 2 in. in diameter and that are removed from property during construction, maintenance, or repair.

C&D waste landfills are classified as Type III Sanitary landfills. Type III Landfills require a liner composed of either a natural soil barrier with a maximum hydraulic conductivity of 1.0×10^{-7} cm/sec, a compacted soil liner with a minimum thickness of 3 ft, a composite liner, or a flexible membrane liner which is not less than 30 mil thick if the liner is installed on stable soil that is not less than 4-ft thick and has a hydraulic conductivity $<1.0\times10^{-5}$ cm/sec. Other liner materials, modified soils, or technologically advanced liner systems may be approved. Type III landfills that have a liner shall have a permanent minimum clearance of 4 ft from the top of the liner to the groundwater table. Leachate collection systems for Type III landfills shall be designed, constructed, and operated to limit the head at the lowest point in the system to not more than 1 ft. Leachate that is removed shall either be reintroduced into the landfill or shall be conveyed to a wastewater treatment facility that is capable of treating the leachate to meet appropriate discharge standards.

Groundwater monitoring through a minimum of quarterly analyses of the monitoring wells is required during the landfill's operation. Following the closure of the landfill, semiannual sampling and reporting are required during the 30-year post-closure period. If groundwater cannot be monitored, then a site shall have a leachate leak detection system. A suitable cover material shall be placed on all exposed solid waste at a Type III landfill by the end of each working day to prevent fugitive dust, blowing litter, and other nuisances.

2.2.23 Minnesota

The Minnesota Pollution Control Agency (MCPA) is the solid waste regulating authority. Solid waste rules are within the Minnesota Administrative Rules Chapter 7035 and specifically Demolition Land Disposal Facilities are addressed within 7035.2825. Demolition debris is defined as solid waste resulting from the demolition of buildings, roads, and other structures including concrete, brick, bituminous concrete, untreated wood, masonry, glass, trees, rock, and plastic building parts. Demolition debris does not include asbestos wastes.

Demolition debris is disposed of within demolition debris landfills, which can be granted PBR status or be required to obtain a permit. PBR facilities cannot be located in an area where the bottom layer of waste is less than 5 ft from the water table, they may be in operation for only one year, and they cannot accept more than 15,000 yd^3 (compacted) of waste. The cost of permitting a facility is often prohibitive for many of the small county sites. The PBR option allows the state to loosely observe these sites through a notification process to deter negligence and illegal dumping without undue financial burden on smaller counties. Plans to update PBR provisions have been discussed.

Regulatory language states that both PBR facilities and permitted facilities must provide monthly cover of waste at a minimum, but do not require liners, leachate collection, or groundwater monitoring. In 2003 the state conducted an evaluation of limited groundwater monitoring data from demolition landfills and recognized that some facilities were impacting groundwater quality. As a result of this study, a Demolition Landfill Guidance document was created to improve how demolition landfills are managed by the solid waste management rules. The document more narrowly classifies demolition landfills and identifies additional management and monitoring that should be required for each class. This document is used in the permitting process for facilities, and therefore such requirements are written into a facility's permit.

From the guidance document, Class I demolition landfills can only accept a specific list of C&D materials. The need for groundwater monitoring is determined by using a matrix that compares depth to groundwater and soil types underneath the waste. Class I facilities normally do not require liners. Class II facilities accept a few additional waste items (incidental non-recyclable packaging consisting of paper, cardboard and plastic, and limited demo-like industrial waste) in addition to Class I waste materials. Groundwater monitoring is required for Class II demolition landfills; to determine if a liner is required, a liner matrix, similar to the groundwater matrix, compares depth to groundwater and the soil type underneath the waste. Class III demolition landfills may accept all C&D wastes and most industrial wastes. Groundwater monitoring and a liner are both required for Class III sites. The state collects demolition landfill groundwater data. Each demolition landfill facility submits an annual report in which any detection above intervention limits (ILs) (1/4 of applicable MCL or SMCL) are noted and corrective actions are proposed, as applicable.

2.2.24 Mississippi

The Mississippi Department of Environmental Quality is the solid waste regulating authority. The Mississippi Commission on Environmental Quality Regulation SW-2: Nonhazardous Solid Waste Management Regulations & Criteria describes C&D type waste materials as components within industrial solid waste and rubbish waste. The final disposal destination of industrial waste is not described beyond disposal within a municipal landfill; however, rubbish waste is disposed of at rubbish sites. Class I rubbish sites can receive wastes including C&D debris, such as wood and metal, and also brick, mortar, concrete, stone, and asphalt, cardboard boxes, natural vegetation, such as tree limbs, stumps, and leaves, appliances (other than refrigerators and air conditioners) that have had the motor removed, furniture, plastic, glass, crockery, and metal, except containers, sawdust, wood shavings, and wood chips, and other similar wastes specifically approved by the Department. Class II rubbish sites receive mostly natural

vegetation, such as tree limbs, stumps, and leaves. Materials such as brick, mortar, concrete, stone, and asphalt and other similar rubbish materials can also be accepted.

Class I rubbish sites must have a liner which is comprised of naturally occurring geological materials (or a constructed alternative) underneath the disposal area (5 ft thick) and on all sidewalls (extending 3 ft laterally). The liner material should consist of clays, silty clays, clayey silts, or other soils that are of low permeability. There must also be an additional 5 ft of material underneath the liner so that the minimum distance from the bottom of the waste to the groundwater table is 10 ft. Leachate collection is not required primarily because any runoff from the site should be controlled by stormwater drainage, and the rubbish materials disposed are expected to have low solubility.

Class II rubbish sites do not require a liner or leachate collection system, although permit approval may be contingent on installation of a liner. Groundwater monitoring is not required for either Class I or II rubbish sites and at a minimum, 6 in of earthen cover material is required to be placed on waste at either type of site, every 2 weeks. Both types of facilities have provisions addressing fire prevention and protection including having an adequate supply of water under pressure at the site or an adequate stockpile of earthen material reasonably close to the disposal area, or a nearby, organized fire department providing service when called. When an accidental fire occurs, action is to be taken to extinguish the fire, and the Department should be notified.

2.2.25 Missouri

The Department of Natural Resources is the solid waste regulating authority. Within the Code of State Regulations, Division 80 Solid Waste Management, the disposal requirements for demolition waste are described. The definition of C&D waste includes waste materials from the construction and demolition of residential, industrial, or commercial structures. Clean fill that is not considered to be C&D waste is defined as uncontaminated soil, rock, sand, gravel, concrete, asphaltic concrete, cinderblocks, brick, minimal amounts of wood and metal, and approved inert solids. These materials are typically used for fill, reclamation, or other beneficial uses. Demolition landfills are solid waste disposal areas used for the controlled disposal of demolition wastes; construction waste; brush; wood wastes; cut, chipped, or shredded tires as defined in 10 CSR 80-8; soil; rock; and concrete and inert solids insoluble in water. The demolition wastes are not to contain more than a minor amount of metals.

Demolition landfills have regulatory provisions for a liner, leachate collection, gas control, groundwater monitoring, daily cover, and fire prevention and control. For the liner system, the bottom liner is required to be composed of at least 2 ft of compacted soil with a hydraulic conductivity of no more than 1×10^{-7} cm/sec and the upper liner a 30-mil thick geomembrane (60 mil if HDPE is used). Leachate collection should maintain no more than 1 ft of leachate on the liner at one time and should have an incorporated recirculation system. Groundwater monitoring wells, at least one upgradient and three downgradient are required. Decomposition gases should be controlled by flaring or ventilation onsite to prevent the endangerment of public health or the environment. A CH_4 control plan is required; if levels of CH_4 are detected above threshold levels, the facility must notify the Department and take actions to protect public health and safety. At least 1 ft of cover must be placed on disposed waste once every 7 days. Fire prevention and control methods include maintaining fire extinguishers on all solid waste handling equipment, extinguishing any fires occurring on the working face, and providing adequate communication for emergency situations.

2.2.26 Montana

Solid waste in Montana is regulated by the Montana Department of Environmental Quality (MDEQ). C&D waste is defined by MDEQ as the waste building materials, packaging, and rubble resulting from construction, remodeling, repair, and demolition operations on pavements, houses, commercial buildings, and other structures, once municipal, household, commercial, and industrial wastes have been removed. It

is further defined as a Group IV waste, which includes C&D wastes and asphalt, and is disposed of in Class IV landfills. The regulations regarding Class IV waste and landfills are found in Chapter 50, Solid Waste Management of the Administrative Rules of the State of Montana Title 17.

Liners for Class IV landfills are conditionally required. Facility designs must ensure that specific MCL concentrations of parameters in the groundwater will not be exceeded. Meeting this requirement is determined by the location of the site, with MDEQ considering the hydrogeologic characteristics of the site location and surrounding lands, climatic factors of the area, and volume and chemical characteristics of the leachate by a point of compliance no more than 150 m (492 ft) away from the waste management boundary. If the MCLs are expected to be exceeded, a composite liner as well as a leachate collection and removal system designed to maintain less than a 30-cm (~12 in) depth of leachate over the liner is required. A liner is not required for a Class IV landfill located within the groundwater monitoring network of a Class II (MSW) landfill. Groundwater monitoring is required for Class IV landfills. An approved cover is required to be applied at a minimum of every 3 months to minimize litter, odor, and leachate. Explosive gas controls required for Class II landfills regarding CH_4 shall also be implemented at Class IV facilities.

2.2.27 Nebraska

Nebraska's Solid Waste Management program is regulated by the Nebraska Department of Environmental Quality (NDEQ). C&D waste is defined by NDEQ as waste which results from construction projects, land clearing, the demolition of buildings, roads or other structures, including, but not limited to, fill materials, wood (including painted and treated wood), land clearing debris other than yard waste, wall coverings (including wall paper, paneling, and tile), drywall, plaster, non-asbestos insulation, roofing shingles and other roof coverings, plumbing fixtures, glass, plastic, carpeting, electrical wiring, pipe, and metals. Excluded from the definition of C&D Waste are friable asbestos waste, special waste, liquid waste, hazardous waste and waste that contains polychlorinated biphenyl (PCB), putrescible waste, household waste, industrial solid waste, corrugated cardboard, appliances, tires, drums, and fuel tanks. C&D waste can only be disposed of in C&D waste disposal areas, regulated under Title 132 Integrated Solid Waste Management Rules, Chapter 5.

Nebraska has no requirements for bottom liners, leachate collection, or groundwater monitoring in C&D waste disposal areas. However, a 10 ft vertical distance between the lowest point of the waste and the maximum water table elevation must be maintained. Periodic cover is required in order to adequately control litter, fires, and disease vectors. Permits for C&D landfills are issued by NDEQ for 5-year terms, and can be renewed again after application for renewal.

2.2.28 Nevada

Nevada's solid waste is regulated by the Nevada Division of Environmental Protection. C&D waste falls under the categories of "rubbish" and "industrial solid waste," which are disposed of in Class III landfills as regulated in the Nevada Administrative Code Chapter 444 Sections 570-7499. Industrial waste defined includes specifically construction, refurbishing or demolition waste from buildings or other structures. Rubbish is defined as non-putrescible solid waste, consisting of both combustible and noncombustible wastes such as paper, cardboard, abandoned automobiles, tin cans, wood, glass, bedding, crockery, and similar materials.

Class III landfills do not require bottom liners or leachate collection systems; however, it is recognized that waters of the state must be protected from degradation by pollutants or contaminants. Therefore, groundwater monitoring is required, with the need for a system capable of monitoring the unsaturated zone or groundwater depending on local conditions. However, due to the arid climate in Nevada, many facilities can obtain an exemption from requirements to monitor groundwater. Daily inspection and cover are required for litter control.

2.2.29 New Hampshire

New Hampshire's solid waste is regulated by the Department of Environmental Services, Waste Management Division. C&D debris and inert construction and demolition debris are defined and regulated by the New Hampshire Code of Administrative Rules Chapter Env-Sw 800: Landfill Requirements. C&D debris is defined as non-putrescible waste building materials and rubble that is solid waste resulting from the construction, remodeling, repair, or demolition of structures or roads. The term includes**,** but is not limited to, bricks, concrete and other masonry materials, wood, wall coverings, plaster, dry wall, plumbing, fixtures, non-asbestos insulation or roofing shingles, asphaltic pavement, and glass. Inert C&D debris means C&D debris that is comprised of materials that do not degrade, combust, or generate leachate. C&D wastes are disposed of in construction/demolition debris (C&D) landfills.

C&D landfills are required to be single-lined (either a 60-mil geomembrane or a 3 ft thick compacted soil liner) facilities, and can be required to be double-lined if the characteristics of the waste pose a threat to groundwater quality. However, landfills that only receive inert C&D debris or stumps and brush can be designed as unlined landfills. A leachate collection and removal system is also required for C&D landfills, as well as groundwater monitoring at all landfills.

2.2.30 New Jersey

The New Jersey Department of Environmental Protection Solid and Hazardous Waste Program regulates solid waste in New Jersey. C&D waste (Type 13C) is defined as waste building material and rubble resulting from construction, remodeling, repair, and demolition operations on houses, commercial buildings, pavements, and other structures. This includes wastes such as treated and untreated wood scrap, tree parts, tree stumps and brush, concrete, asphalt, bricks, blocks and other masonry, plaster and wallboard, roofing materials, corrugated cardboard and miscellaneous paper, ferrous and non-ferrous metal, plastic scrap, dirt, carpets and padding; glass (window and door), non-asbestos building insulation, and other miscellaneous materials. Bulky waste (Type 13) is also defined as including items such as tree trunks, auto bodies, demolition or construction materials, appliances, furniture, and drums. These wastes are to be disposed of in Class III sanitary landfills, which accept inert waste of types 13 and 23 (vegetative waste), as dictated by Title 7: Environmental Protection of the New Jersey Administrative Code Chapter 26: Solid Waste, Subchapter 2: Disposal.

A composite liner system consisting of a geomembrane liner with a 2 ft layer of compacted clay, or equivalent, and hydraulic conductivity $<1\times10^{-7}$ cm/sec at a minimum is required at the landfills, as well as a leachate collection system. Groundwater monitoring is also required at the landfills, as well as gas venting systems. Adequate water supply and fire-fighting equipment are to be maintained at the facility or be readily available. Areas where waste has been deposited shall be covered daily. Type 13 and 13C wastes can also be disposed of at Class I MSWLF facilities.

Although landfills are identified for C&D material waste disposal, the majority of this waste type in New Jersey is intended for recovery at transfer stations and material recovery facilities (TS/MRFs). At the TS/MRFs, the waste is sorted manually or by mechanical systems to extract recyclables. The small residuals from the sorting process can either be disposed of or applied as landfill cover, provided that it satisfies chemical and physical performance criteria as cover materials and it is approved for use by the Department of Environmental Protection. These transfer stations are common in the central and northern part of the state, where landfills rarely receive C&D. In the southern part of New Jersey, most C&D Type 13 and 13C waste is disposed of in Class I MSWLFs that are equipped to receive these wastes in specific cells. There is one Type II landfill that receives C&D and bulky waste, in addition to Type 27 dry industrial waste.

2.2.31 New Mexico

The New Mexico Environment Department Solid Waste Bureau regulates solid waste in New Mexico. Construction and demolition waste is disposed of in a Construction and Demolition Landfill, which is a landfill that receives only C&D debris in quantities equal to or less than 50 tpd on a monthly average. Any landfill that receives more than 50 tpd monthly average of C&D debris waste in any month is defined as a municipal landfill, as defined by 20.9 New Mexico Administrative Code (NMAC). C&D debris is also disposed with MSW in municipal landfills.

Bottom liners are not required for C&D landfills. Groundwater monitoring for C&D landfills is not required unless there is the potential for constituents to migrate to the uppermost aquifer. In an effort to control vectors and reduce the risk of fire, soil cover should be applied and compacted at the end of each operating day. The generation and migration of CH_4 must be prevented so that the concentration of CH_4 generated by the facility does not exceed 25% of the lower explosive limit (LEL) for CH_4 in facility structures or 100% of the LEL at the property boundary. As a matter of reviewing and proposing permit applications for approval, it is likely that the Solid Waste Bureau would require CH_4 monitoring at C&D landfills in the future to ensure that they are compliant with the requirements of 20.9.5.10.C NMAC.

2.2.32 New York

The New York State Department of Environmental Conservation regulates solid waste and specifically C&D debris landfills in the State of New York, as specified in 360-7 of Chapter 4: Quality Services, except for C&D debris landfills located on Long Island (Nassau and Suffolk Counties), which are regulated under 360-8. C&D debris is defined as uncontaminated solid waste resulting from the construction, remodeling, repair, and demolition of utilities, structures and roads; and uncontaminated solid waste resulting from land clearing. Such waste includes, but is not limited to bricks, concrete and other masonry materials, soil, rock, wood (including painted, treated and coated wood and wood products), land clearing debris, wall coverings, plaster, drywall, plumbing fixtures, non-asbestos insulation, roofing shingles and other roof coverings, asphaltic pavement, glass, plastics that are not sealed in a manner that conceals other wastes, empty buckets 10 gal or less in size and having no more than 1 in. of residue remaining on the bottom, electrical wiring and components containing no hazardous liquids, pipe, and metals that are incidental to any of the above. Land clearing debris is vegetative matter, soil, and rock resulting from activities such as land clearing and grubbing, utility line maintenance or seasonal or storm-related cleanup such as trees, stumps, brush and leaves and including wood chips generated from these materials.

C&D debris can be disposed of in exempt, registered, or permitted C&D debris landfills. Exempt C&D debris landfills may accept only asphalt pavement, brick, glass, soil, and rock, and are exempt from permitting. Registered C&D debris landfills are land clearing debris landfills of 3 acres or less, which may also accept recognizable, uncontaminated concrete, concrete products, asphalt pavement, brick, glass, soil, and rock. Exempt and registered C&D debris landfills do not require liners, leachate collection systems, or groundwater monitoring.

The remaining C&D debris is disposed of in permitted C&D debris landfills, which are further divided into landfills 3 acres or less and landfills larger than 3 acres. Liners are required for both types of permitted facilities; landfills 3 acres or less require a base liner of 2 ft of soil with a hydraulic conductivity of 1×10^{-5} cm/sec. C&D debris landfills greater than 3 acres require a single composite liner, comprised of a 60 mil geomembrane over a 24 in compacted soil layer, with a hydraulic conductivity $\leq1\times10^{-7}$ cm/sec.

All permitted C&D debris landfills require a 5 ft buffer between the base of the liner and the seasonal high groundwater table, as well as a 10 ft buffer between the base of the liner and bedrock. For C&D debris landfills 3 acres or less in size that accept no more than 200 tons per week and no pulverized C&D

debris, leachate collection is not required, and groundwater monitoring is conditional, based on the size and expected life of the facility, as well as its distance to potential groundwater users. For C&D debris landfills greater than 3 acres in size, leachate collection is required, with a maximum of 1 ft of head on the liner, as well as groundwater monitoring. Cover must be applied to control odors, fire hazards, vectors, and litter. Gas venting systems are necessary for all C&D debris landfills greater than 3 acres upon closure and may be required for those less than or equal to 3 acres in size.

2.2.33 North Carolina

The North Carolina Department of Environment and Natural Resources, Division of Waste Management regulates solid waste, specifically C&D waste, under 15A North Carolina Administrative Code 13B .0532-.0547. C&D solid waste is defined as solid waste generated solely from the construction, remodeling, repair, or demolition operations on pavement and buildings or structures. C&D waste does not include municipal or industrial wastes that may be generated by the ongoing operations at buildings or structures. This waste is disposed of in C&D solid waste landfills (C&DLF). Following the passing of the Solid Waste Management Act of 2007, new C&D landfills are required to have a liner and leachate collection system per the statute. Landfills in existence prior to August 1, 2006, are not subject to the liner requirement. This condition has not yet been reflected in the rules. A groundwater monitoring system is required, and must consist of wells to represent the quality of background groundwater as well as groundwater passing relevant points of compliance and downgradient wells. Open burning at a C&DLF is prohibited, and equipment must be provided at the facility to control accidental fires as well as arrangements made with the local fire protection agency to immediately provide services when needed. Cover requirements of 6 in. of earthen material applied at least weekly or when the waste disposal area exceeds one half acre are in place to control disease vectors, fires, odors, blowing litter, and scavenging.

2.2.34 North Dakota

In North Dakota, solid waste is regulated by the North Dakota Department of Health, Division of Waste Management. Inert waste is also regulated, which is defined as non-putrescible solid waste that will not generally contaminate water or form a contaminated leachate, and includes but is not limited to: C&D material such as metal, wood, bricks, masonry and cement concrete; asphalt concrete; metal; tree branches; bottom ash from coal fired boilers; and waste coal fines from air pollution control equipment. Because C&D waste falls under this definition, it is disposed of in inert waste landfills as regulated by the North Dakota Administrative Code 33-20-05.

There are no liner or leachate collection requirements for inert waste landfills due to the clayey nature of soils in North Dakota; however, there are location restrictions based on other geophysical conditions of the site. Groundwater monitoring is also not required for inert waste landfills in North Dakota. Cover of 6 in. of earthen material is required at a minimum of two times per year. Final cover requirements are at least 2 ft of final soil cover, including 6 in. of topsoil.

2.2.35 Ohio

The Ohio Environmental Protection Agency (OEPA) Division of Materials and Waste Management (DMWM) regulates construction and demolition debris (C&DD) in Ohio, under Ohio Administrative Code (OAC) Chapter 3745-400. C&DD refers to those materials resulting from the alteration, construction, destruction, rehabilitation, or repair of any manmade physical structure, including, without limitation, houses, buildings, industrial or commercial facilities, or roadways. This includes materials such as brick, concrete and other masonry materials, stone, glass, wall coverings, plaster, drywall, framing and finishing lumber, roofing materials, plumbing fixtures, heating equipment, electrical wiring and components containing no hazardous fluids or refrigerants, insulation, wall-to-wall carpeting, asphaltic substances, metals incidental to any of the above, and weathered railroad ties and utility poles.

This waste is disposed of in C&DD landfills or may go to MSWLFs, especially in areas that do not have access to a C&DD facility.

Areas of C&DD landfills constructed after 1996 are required to have liners, whether in the form of in-situ materials that have a minimum thickness of 5 ft and maximum permeability of 1×10^{-5} cm/sec or a maximum permeability equivalent to two feet of soil of 1×10^{-6} cm/sec, or the required re-compacted soil liner of thickness 24 in. built in 8 in. lifts and a maximum permeability of 1×10^{-6} cm/sec for each lift. Leachate collection systems are required for both in-situ and constructed liner systems, and shall be designed to maintain less than 1 ft of head on the liner. Liners and groundwater monitoring are required at C&DD landfills in Ohio, unless it meets all the requirements in paragraph (A) of rule 3745-400-10 of the Administrative Code, based on the location of the C&DD landfill to the nearest aquifer and water supply system and the permeability of the materials in between. Fire protection for C&DD landfills is taken into account by applying cover to all disposed debris on a weekly basis with soil, clean hard fill, or any other noncombustible material. Fire control equipment is also necessary at or near the facility.

OEPA has had a focus on C&DD landfill properties as a result of growing concerns about impacts from C&DD landfills. Further discussion of the examinations conducted by OEPA on leachate quality and groundwater impacts from C&DD landfills is presented in Section 3 of this report. Recent regulation changes that were promulgated on August 1, 2012, established new rules for C&DD landfills, including a 5-year post-closure care period, financial assurance for post-closure and closure care, and leachate sampling requirements.

2.2.36 Oklahoma

The Oklahoma Department of Environmental Quality regulates solid waste through the Oklahoma Administrative Code Title 252 Chapter 515 Management of Solid Waste. C/D waste is defined as waste composed of asbestos-free waste from construction and/or demolition projects that may include such materials as metal, concrete, brick, asphalt, glass, roofing materials, limited amounts of packing materials, sheetrock, or lumber; wood waste that may include such materials as yard waste, lumber, wood chips, wood shavings, sawdust, plywood, tree limbs, or tree stumps; yard waste that may include such materials as grass clippings, tree limbs, tree stumps, shrubbery, flowers, or other vegetative matter resulting from land clearing or landscaping operations; or residential lead-based paint waste. This waste is disposed of in C&D landfills.

C&D landfills are required to have an in-situ liner or a reconstructed clay liner. The in-situ liner must have a minimum separation of 15 ft from waste to the highest groundwater elevation, and be 5-ft thick with a maximum hydraulic conductivity of 1×10^{-5} cm/sec. Otherwise, a reconstructed clay liner of at least 3 ft in thickness is required with a hydraulic conductivity of maximum 1×10^{-5} cm/sec. C&D Landfills are not subject to leachate collection requirements. Groundwater monitoring is required for all C&D Landfills, for the parameters of pH, chemical oxygen demand (COD), and conductivity. Cover shall be applied weekly for the control of disease vectors, fires, odors, litter, and scavenging. Gas monitoring by use of probes is required at C&D landfills.

2.2.37 Oregon

In Oregon, solid waste is regulated by the Oregon Department of Environmental Quality. C&D waste is defined in Oregon rules as solid waste resulting from the construction, repair, or demolition of buildings, roads and other structures, and debris from the clearing of land, but does not include clean fill when separated from other C&D wastes and used as fill materials or otherwise land disposed. Such waste typically consists of materials including concrete, bricks, bituminous concrete, asphalt paving, untreated or chemically treated wood, glass, masonry, roofing, siding, plaster; and soils, rock, stumps, boulders, brush and other similar material. This term does not include industrial solid waste and MSW generated in residential or commercial activities associated with construction and demolition activities.

C&D landfills are landfills that receive only C&D waste. There are relatively few C&D landfills in Oregon, and most of the C&D waste disposed goes to MSW landfills. C&D landfills are regulated under Oregon Administrative Rules Chapter 340 Division 95: Land Disposal other than MSWLFs. Inert waste is defined as waste containing only constituents that are biologically and chemically inactive and that, when exposed to biodegradation and/or leaching, will not adversely impact the waters of the state or public health.

Liner and leachate collection systems at C&D landfills are conditionally required – determining factors include the site's size, incoming waste amount, or geophysical conditions. Groundwater monitoring is also conditional and can be dependent on whether a landfill's location and geophysical condition indicate that there is a reasonable probability of potential adverse effects on public health or the environment. If so, the Department may require the permittee to provide monitoring wells at Department-approved locations and depths to determine the effects of the non-municipal land disposal site on groundwater. Gas controls must be in place so that CH_4 at the landfill does not exceed 25% of its LEL in facility structures, or at the property boundary and that malodorous decomposition gases do not become a public nuisance. Cover must be placed in layers of at least 6 in. at intervals specified in a site's permit, and arrangements with the local fire protection agency and on-site fire-fighting methods must also be demonstrated.

2.2.38 Pennsylvania

Solid waste in Pennsylvania is regulated by the Pennsylvania Department of Environmental Protection. As described by the Pennsylvania Code Title 25, Chapter 277, C/D waste is defined as solid waste resulting from the construction or demolition of buildings and other structures, including, but not limited to, wood, plaster, metals, asphaltic substances, bricks, block and unsegregated concrete. The term C/D waste does not apply to uncontaminated soil, rock, stone, gravel, brick and block, concrete and used asphalt, and waste from land clearing if they are separate from other waste and are used as clean fill. C/D waste is disposed of in C/D landfills.

C/D landfills are required to have a liner system with a subbase, leachate detection zone, a liner that is a continuous layer of remolded clay or synthetic material liner, a protective cover and leachate collection zone that is a prepared layer placed over the liner in which a leachate collection system is located. The leachate collection system, among other requirements, shall ensure that there is a maximum of 1 ft of head on the liner. Groundwater monitoring is also a requirement for C/D Landfills, which entails measuring groundwater quality upgradient, beneath, and downgradient of the C/D waste disposal area. Cover is to be placed on lifts of 50 ft horizontally or on a weekly basis, whichever occurs first. The cover material should be capable of controlling fires and stabilizing the area. If the cover is soil-like, a minimum of 12 in. shall be applied, and a 2 week supply shall be maintained on site. If the waste disposed of generates or is likely to generate gas, the operator shall then implement gas control and monitoring.

2.2.39 Rhode Island

Solid waste in Rhode Island is regulated by the Department of Environmental Management, Office of Waste Management. C&D debris is defined as non-hazardous solid waste resulting from the construction, remodeling, repair, and demolition of utilities and structures; and uncontaminated solid waste resulting from land clearing. Such waste includes, but is not limited to, wood (including painted, treated and coated wood and wood products), land clearing debris, wall coverings, plaster, drywall, plumbing fixtures, non-asbestos insulation, roofing shingles and other roofing coverings, glass, plastics that are not sealed in a manner that conceals other wastes, empty buckets ten gallons or less in size and having no more than 1 in. of residue remaining on the bottom, electrical wiring and components containing no hazardous liquids, and pipe and metals that are incidental to any of the above. Solid waste that is not C&D debris (even if resulting from the construction, remodeling, repair, and demolition of utilities, structures, and roads and land clearing) includes, but is not limited to, asbestos waste, garbage, corrugated container board, electrical fixtures containing hazardous liquids such as fluorescent light ballasts or transformers,

fluorescent lights, carpeting, furniture, appliances, tires, drums, containers greater than ten gallons in size, any containers having more than 1 in. of residue remaining on the bottom, and fuel tanks. Also excluded from the definition of C&D debris is solid waste resulting from any processing technique that renders individual waste components unrecognizable, such as pulverizing or shredding, at a facility that processes C&D debris.

C&D debris that is disposed of in Rhode Island is placed in MSWLFs, otherwise the C&D debris is handled by C&D debris processing facilities, which are regulated by Solid Waste Regulation No. 7: Facilities that Process Construction and Demolition Debris. Facilities that receive less than 50 tpd of C&D debris are exempt from the requirement to obtain a solid waste management facility license; instead, they must go through a registration process and comply with all other applicable requirements and regulations. Groundwater monitoring is conditional at C&D debris processing facilities, and may be required by the Department based on size, type, and location of the facility, length of time materials will be stored, and proximity to drinking water wells and surface water bodies. A fire protection plan that has been approved by the local fire chief is necessary for all facilities and an adequate supply of water under pressure or cover material designated for firefighting is required.

2.2.40 South Carolina

Solid waste in South Carolina is regulated by the South Carolina Department of Health and Environmental Control. C&D debris is defined as discarded solid wastes resulting from construction, remodeling, repair and demolition of structures, road building, and land clearing. These wastes include, but are not limited to, bricks, concrete, and other masonry materials, soil, rock, lumber, road spoils, paving material, and tree and brush stumps, but do not include solid waste from agricultural or silviculture operations. C&D debris is disposed of in Class Two landfills, as regulated by 61-107.19 Part IV of the South Carolina Code of Regulations. Class Two landfills accept C&D debris in addition to land clearing debris and vegetation, tires, and asbestos containing material. There are no liner or leachate collection requirements for Class Two landfills; however, groundwater monitoring is required. A minimum of one upgradient well and three wells downgradient of the landfill are required to monitor groundwater quality. Clean earth cover of no less than 6 in. shall be applied onto exposed waste every 30 days.

2.2.41 South Dakota

In South Dakota, solid waste is regulated by the Department of Environment and Natural Resources. C&D debris is defined in South Dakota as waste building materials resulting from construction, remodeling, repair, and demolition operations on pavements, houses, commercial buildings, and other structures, excluding regulated asbestos-containing waste material or ash. This waste is disposed of in inert waste disposal facilities, or restricted use sites which are regulated under both general permits and individual permits, and follow certain portions of the Administrative Rules of South Dakota, Article 74:27. There are no liner or leachate collection system requirements for these inert waste and restricted use facilities. Groundwater monitoring is also not required for these sites, as location is taken into consideration when permitting a site to avoid the need for groundwater monitoring. A fire lane at least 25 ft wide around the active disposal area and within the perimeter fence is required for fire control.

2.2.42 Tennessee

Solid waste in Tennessee is regulated by the Department of Environment and Conservation, Division of Solid Waste Management. C/D waste is defined to mean wastes, other than special wastes, resulting from construction, remodeling, repair and demolition of structures and from road building. Such wastes include but are not limited to bricks, concrete and other masonry materials, soil, rock and lumber, road spoils, rebar, paving material. Prior to 2008, C/D wastes were disposed of in Class IV landfills. As of July 1, 2008 C/D wastes have been required to be disposed of in Class III landfills, which also allow the disposal of shredded tires, and certain wastes with similar characteristics as approved by the Department. Class III

and IV landfills are regulated by Chapter 1200-01-07-.04 of the Rules of Tennessee Department of Environment and Conservation.

Although no composite liner system is required at Class III or IV landfills, there is a requirement for either a 10-ft thick geologic buffer having a maximum hydraulic conductivity of 1×10^{-5} cm/sec, and located such that its uppermost surface is at least 10 ft above the seasonal high water table, or for a 5 ft thick geologic buffer having a maximum hydraulic conductivity of 1×10^{-6} cm/sec and located such that its uppermost surface is at least 5 ft above the seasonal high water table. No leachate collection system is required at Class III landfills. A groundwater monitoring system is required, and groundwater protection standards must be met. At a minimum, Class III disposal facilities shall cover waste every 14 days, and Class IV every 30 days, with at least 6 in. of compacted soil or adequate equivalent in order to prevent fire hazards, harmful releases, and control disease vectors. In Class III landfills, quarterly gas monitoring shall take place at the landfill facility.

2.2.43 Texas

Solid waste in Texas is regulated by the Texas Commission on Environmental Quality (TCEQ) by Title 30, Texas Administrative Code, Chapter 330. Texas defines C&D waste as "waste resulting from construction or demolition projects; includes all materials that are directly or indirectly the by-products of construction work or that result from demolition of buildings and other structures, including, but not limited to, paper, cartons, gypsum board, wood, excelsior, rubber, and plastics." C&D waste may be disposed at both Type I landfills, which may accept all forms of MSW, and Type IV landfills, which are limited to non-putrescible wastes which include brush, C&D waste, and rubbish. C&D wastes can also be disposed of at landfills classified as Type IAE and Type IVAE, which accept the same waste types, but are regulated based on waste acceptance rates and location. Arid exempt landfills are exempt from requiring a liner and groundwater monitoring.

Type IV landfills must have a liner, which can be a 4 ft thick layer of in-situ soil between the waste and groundwater that has a hydraulic conductivity of 1×10^{-7} cm/sec or a re-compacted clay liner with a 3-ft thick buffer between the waste and the groundwater, a hydraulic conductivity of 1×10^{-7} cm/sec, and a 1-ft thick protective soil layer over the re-compacted clay layer. Leachate collection is not required. Groundwater monitoring in Type IV landfills is conditional, as it may be required by the TCEQ executive director with wells sampled annually. All Type IV facilities must apply 6 in. of earthen material cover on a weekly basis at a minimum to control disease vectors, fires, odors, and litter.

2.2.44 Utah

The Utah Department of Environmental Quality, Division of Solid & Hazardous Waste regulates solid waste. C/D waste is defined as solid waste from building materials, packaging, and rubble resulting from construction, remodeling, repair, abatement, rehabilitation, renovation, and demolition operations on pavements, houses, commercial buildings, and other structures, including waste from a conditionally exempt small quantity generator of hazardous waste, as defined by Section R315-2-5, that may be generated by these operations. These types of wastes include concrete, bricks, and other masonry materials, soil and rock, waste asphalt, rebar contained in concrete, untreated wood, and tree stumps. As defined in Rule 305 of Utah Administrative Code Title 315, C/D Waste is disposed of in Class IV landfills, which are non-commercial landfills that can also accept yard waste, inert waste, dead animals, waste tires, and petroleum contaminated soils if they meet certain requirements.

Class IV landfills are further classified as Class IVa landfills, which receive over 20 tons of waste per day and as a component, CESQG waste, and Class IVb landfills, which receive less than 20 tpd or that receive over 20 tpd and that do not accept CESQG waste. C/D aste can also be disposed of in Class VI landfills, which are commercial nonhazardous landfills and accept the same waste types as Class IV landfills except for CESQG hazardous waste which they are not allowed to accept. There are no liner or leachate

collection system requirements for Class IV or VI landfills. Groundwater monitoring is considered conditional, as only Class IVa landfills require monitoring, as well as landfills located in Salt Lake County. To avoid fires, cover of 6 in. of soil is required over timbers, wood, and other combustible waste on a monthly basis.

2.2.45 Vermont

Solid waste in Vermont is regulated by the Agency of Natural Resources, Department of Environmental Conservation, Waste Management Division. C&D waste is defined as waste derived from the construction or demolition of buildings, roadways or structures including but not limited to clean wood, treated or painted wood, plaster, sheetrock, roofing paper and shingles, insulation, glass, stone, soil, flooring materials, brick, masonry, mortar, incidental metal, furniture and mattresses. The definition of C&D waste excludes CESQG waste. C&D waste is disposed of in discrete disposal facilities, which refers to facilities other than diffuse disposal facilities used for solid waste disposal.

These discrete disposal facilities are regulated under the Solid Waste Management Rules, Rule Number 11P-03, and are required to have a liner and leachate collection system. For these facilities, the liners are required to be double liners, with each of the liner components being of a synthetic material or a composite of synthetic and natural materials, with a hydraulic conductivity $\leq 1x10^{-7}$ cm/sec. Liner requirements may be waived if it can be proven that the leachate from the site is not harmful to public health and the environment. Groundwater monitoring is also required, as a discrete disposal facility must demonstrate that it meets the requirements established in 40 CFR 258. Discrete disposal facilities must also be constructed with a minimum 6-ft thick minimum vertical separation from the seasonal high groundwater table. There are no specific cover requirements for discrete disposal facilities containing C&D Waste, although facilities are required to identify a means to control odor, vectors, and dust as part of permitting.

2.2.46 Virginia

The Virginia Department of Environmental Quality (VDEQ) regulates solid waste for the state. Construction waste is defined as solid waste that is produced or generated during construction, remodeling, or repair of pavements, houses, commercial buildings, and other structures. Construction wastes include, but are not limited to lumber, wire, sheetrock, broken brick, shingles, glass, pipes, concrete, paving materials, and metal and plastics if the metal or plastics are a part of the materials of construction or empty containers for such materials. Demolition waste is also defined as solid waste that is produced by the destruction of structures and their foundations and includes the same materials as construction wastes. Additionally, debris waste is defined as wastes resulting from land-clearing operations and include, but are not limited to stumps, wood, brush, leaves, soil, and road spoils. These wastes are disposed of in construction/demolition/debris (CDD) landfills, which are land burial facilities engineered, constructed and operated to contain and isolate construction waste, demolition waste, debris waste, split tires, and white goods or combinations of the above solid wastes, as specified by Title 9 of the Virginia Administrative Code (VAC) Agency 20, Chapter 81 (9 VAC 20-81).

CDD landfills must have a liner of compacted clay, with at least 1 ft with a hydraulic conductivity $<1\times10^{-7}$ cm/sec and covered with a 12 in. thick drainage layer, or a synthetic liner consisting of 30 mil thick flexible membrane or 60-mil thick HDPE, covered with a 12 in. thick drainage layer and 6 in. thick protective layer, both of hydraulic conductivity $\geq 1\times10^{-3}$ cm/sec. A leachate collection system is required to maintain <30 cm of leachate on the liner. Groundwater monitoring is required unless a CDD landfill opts to install a double liner system with a monitoring zone. Compacted soil cover 1 ft thick must be applied weekly for safety and aesthetic purposes, and a fire break line of 50 ft shall be designated between the waste limits and tree lines in order to prevent fires. For CDD Landfills, sites must include a decomposition gas venting system or gas management unless the owner can demonstrate that gas formation is not a concern. At closure, CDD Landfills must install a final cover system of soil only, 18 in.

thick infiltration layer with a hydraulic conductivity ≤ bottom liner hydraulic conductivity or natural subsoils or $<1\times10^{-5}$ cm/sec, whichever is less, and a 6 n. thick erosion layer to support native plant growth, or an alternate system consisting of a GCL or a 40 mil thick geosynthetic membrane, 18 in. thick soil protective cover layer, and 6 in. thick earthen vegetative support layer. After closure, CDD landfills are subject to a minimum 10-year post closure care period.

2.2.47 Washington

The State of Washington Department of Ecology develops regulations for solid waste facilities. Local jurisdictional health departments permit and enforce the state regulations at solid waste facilities in the state. C&D debris is not defined; however, demolition waste is defined under Chapter 173-351 Washington Administrative Code (WAC) as largely inert waste resulting from the demolition of buildings, roads, and other manmade structures. This waste is disposed of in limited purpose landfills. As defined in Chapter 173-350 WAC, a limited purpose landfill is defined as a landfill which is not regulated or permitted by other state or federal environmental regulations that receives solid wastes limited by type or source. Limited purpose landfills include, but are not limited to, landfills that receive segregated industrial solid waste, construction, demolition and land clearing debris, wood waste, ash (other than MSW incinerator ash), and dredged material.

WAC 173-350 establishes several performance standards for limited purpose landfills. A composite liner system consisting of a lower component of minimum 2-ft layer of compacted soil with a hydraulic conductivity of 1×10^{-7} cm/sec, and an upper component of HDPE 60-mil geomembrane installed with direct contact with the lower component is presumed to meet the liner performance standard. A leachate collection system is also required, maintaining less than 1 ft of head over the liner system and 2 ft in leachate sump areas. Groundwater monitoring is required at limited purpose landfills. Cover is required on a daily basis at the end of operation in order to control disease vectors, fires, odors, litter, and scavenging. Components of C&D waste debris such as concrete, brick and masonry, clean soils, rock, and asphalt can be disposed of in inert waste landfills, which do not have liner, leachate collection, or groundwater monitoring requirements.

2.2.48 West Virginia

Solid waste in West Virginia is regulated by the West Virginia Department of Environmental Protection. C/D waste is defined as waste building materials, packaging, and grubbing waste resulting from construction, remodeling, repair, and demolition operations on houses, commercial, and industrial buildings, including, but not limited to, wood, plaster, bricks, blocks and concrete, and other masonry materials. This waste does not include asbestos-containing materials, household furnishings, burnt debris, material containing lead-based paint, pressure-treated wood, contaminated solid waste, yard waste, or waste tires. C/D Wastes are disposed of in Class D and Class D-1 solid waste facilities, regulated by Subdivision 3.16.e., et seq., and Subsection 5.4., et seq., of the Solid Waste Management Rule, Title 33 Series 1 (33CSR1). Class D-1 solid waste facilities are commercial or noncommercial solid waste facilities for the disposal of only C/D waste. Class D solid waste facilities are noncommercial facilities for the disposal of waste materials such as asphalt, masonry products, brush, engineered wood, hardened concrete, packaging materials, and trees, but in an area no greater than 2 acres in size and not exceeding the height of the adjoining ground elevation.

Liner requirements are necessary depending on if the facility is Class D-1 or Class D. A Class D-1 landfill requires a liner with a subbase of cleared natural ground and a 2-ft thick soil liner, compacted in 6 in. lifts with a hydraulic conductivity less than 1×10^{-6} cm/sec. A leachate collection system is also required, as well as groundwater monitoring. For Class D facilities, a liner and a leachate collection system are not required. Groundwater monitoring is not required for a Class D facility; however, a groundwater protection plan must be approved prior to operation. Intermediate cover a minimum of 4 in. thick earthen material, or an alternate material approved by the Department, must be placed once per week over the

disposed waste material, or it must be placed on top of each 6 ft vertical lift of waste material disposed, whichever comes first.

2.2.49 Wisconsin

Solid waste in Wisconsin is regulated by the Department of Natural Resources (WDNR). C&D waste is defined as solid waste resulting from the construction, demolition, or razing of buildings, roads, and other structures. This waste typically consists of concrete, bricks, wood, glass, masonry, roofing, siding and plaster. These wastes are disposed of in small and intermediate size C&D landfills, which are regulated by Chapter NR 503 Wisconsin Administrative Code. Small Size C&D landfills are permitted to accept less than 50,000 yd^3 of material. For small size C&D landfills, a distance of 10 ft separation is required from the base of the landfill to the water table, unless it is located in a clayey soil environment.

Groundwater monitoring is required for small size C&D landfills, with a minimum one well upgradient, and two wells downgradient of the landfill. Intermediate size C&D landfills accept C&D Waste and are permitted for more than 50,000 yd^3 but no more than 250,000 yd^3. Intermediate C&D landfills require a clay liner of thickness of 3 ft, a hydraulic conductivity of 1×10^{-7} cm/sec, and a distance between the bottom of the clay liner and the groundwater table of 10 ft. Intermediate C&D landfills must also have a leachate collection system, as well as leachate monitoring. More extensive groundwater monitoring is required for intermediate size C&D landfills than for small size sites. Cover is required at the end of each operating day with 6 in of soil or alternative material. Additionally, the landfill must be designed with a system allowing gas venting from the landfill surface, unless it has an active gas recovery system. C&D landfills greater than 250,000 yd^3 are regulated as industrial solid waste landfills under Chapter NR 504.

2.2.50 Wyoming

Solid waste is regulated by the Wyoming Department of Environmental Quality. It defines C/D waste as waste that includes but is not limited to stone, wood, concrete, asphaltic concrete, cinder blocks, brick, plaster, and metal. This waste is disposed of in C/D waste landfills, meaning a solid waste management facility that accepts only inert construction waste, demolition waste, street sweepings, and brush, which are regulated by Chapter 4 of the Wyoming Solid Waste Rules. Bottom liner and leachate collection systems at C/D landfills are conditional based on the wastes accepted and site conditions of where the C/D landfill is located. Groundwater monitoring may be required at these facilities. Cover is required for all facilities, with 6 in. of compacted soil at least monthly, though landfills that receive <20 yd^3 of waste per month must cover with 6 in. of compacted soil once the working face depth reaches 3 ft. Fire protection is required by maintaining a minimum 10 ft unobstructed fire lane within the area of the perimeter fence, and personnel having access to portable fire extinguishers as well as a communication system to alert the local fire department.

2.3 Inventory of Active C&D Landfills and C&D Recycling/Processing Facilities

A total of 1,540 active C&D debris landfills and 512 active C&D recycling facilities were identified in the facility inventory using the methodology described previously. The number of active C&D landfills was less than that reported by US EPA (1994), which identified 1,889 C&D landfills, a decrease of approximately 18%. As a point of comparison, the number of MSWLFs in 1994 was 3,558 (US EPA 2008), while the reported number of MSWLFs in 2008 was 1,908 (van Haaren et al. 2010) – a decline of approximately 47%. ***Figure 2-1*** presents a map depicting the distribution of active C&D debris landfills in the US. The data were further examined on a population basis – using US census data from 2010, the distribution of landfills was assessed by grouping each state based on population size as shown in ***Figure 2-2***. The data do not appear to suggest a strong correlation between a state's population size and the number of active C&D debris landfills. For example, states with a population ranging from 1 to 5 million have nearly 45% of all active C&D debris landfills, whereas the number of C&D landfills in the largest states (population greater than 10 million) is slightly less than the number of landfills in the states with the smallest populations.

The relative disparity in the decline of the number of C&D landfills compared to MSWLFs is likely a function of a combination of factors, primarily that no major federal rules in the last 18 years were promulgated impacting C&D debris management, whereas the decline in the number of MSWLFs is largely a function of the federal Subtitle D design and construction requirements for these facilities, which mandates a liner and leachate collection system among other elements. Thus, the trend for MSW to be disposed of in fewer, larger facilities has emerged in recent years. As will be discussed in Section 2.4, several states have increased the stringency of rules related to C&D debris management, which may have contributed somewhat to the decline in the number of C&D landfills compared to the 1994 figure. Note that most states (66%) do not require bottom liners and leachate collection systems, which may explain why the decline in the number of C&D landfills was not as dramatic when compared to MSWLFs. Another factor that likely contributed to the decline in C&D landfills compared to 1994 was the economic downturn that occurred in the US in late 2008, which greatly impacted the construction industry.

Figure 2-3 presents a summary of C&D recycling and processing facilities in the US. Note that the data represent facilities that nearly exclusively process C&D debris, which was determined by obtaining lists of C&D-only processing facilities from the states or by filtering data in the WBJ (2012) database to include only those facilities that listed C&D as the only materials processed. In general, the figure shows that the number of facilities in a given state tends to be greater on the east and west coast. The count of facilities presented in ***Figure 2-3*** contains some gaps and thus likely underestimates the total number of C&D processing facilities in the US. As described further in Section 2.4, several states exempt certain recycling activities from regulation under solid waste rules, and as a result, these activities may not be documented at the state level.

The number of C&D processing facilities as a function of state population was examined as shown in ***Figure 2-4***. In contrast to the C&D disposal facility and population relationship shown in ***Figure 2-2***, there appears to be a strong correlation between a state's population size and the number of C&D processing facilities.

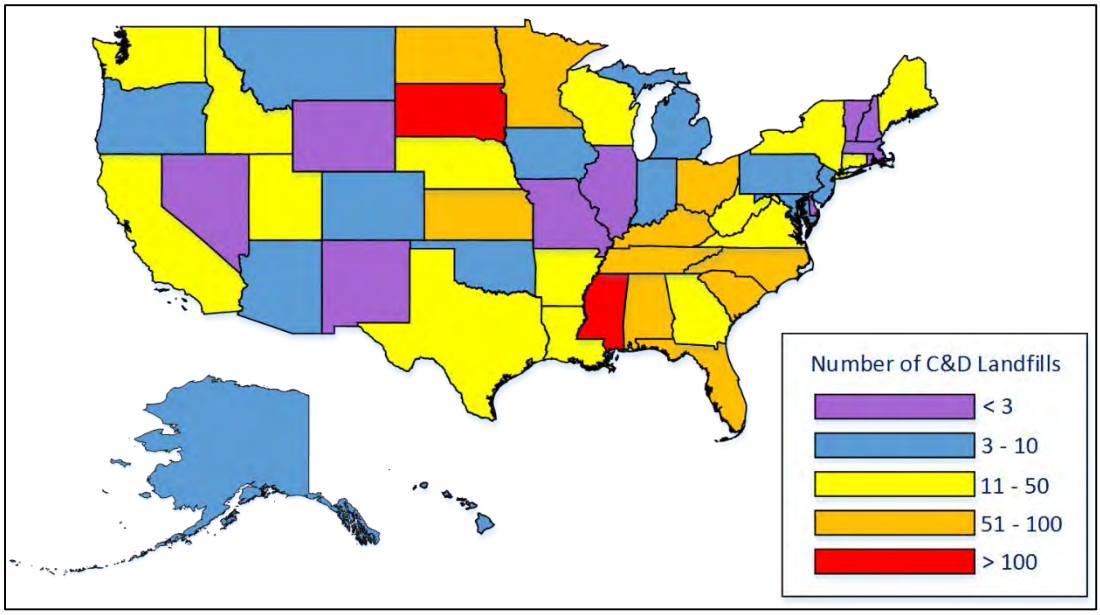

Figure 2-1. US Map Showing Grouped Distribution of the Number of Active C&D Landfills Based on State Solid Waste Databases as of 2012

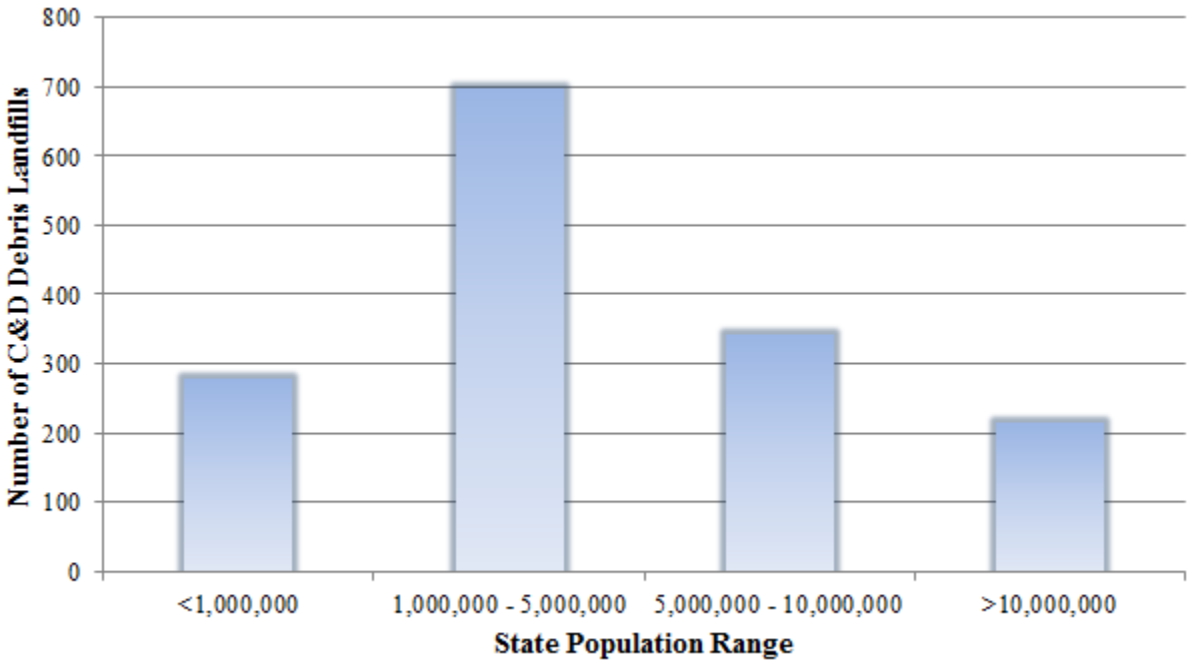

Figure 2-2. Distribution of the Number of C&D Debris Landfills in the US as a Function of State Population

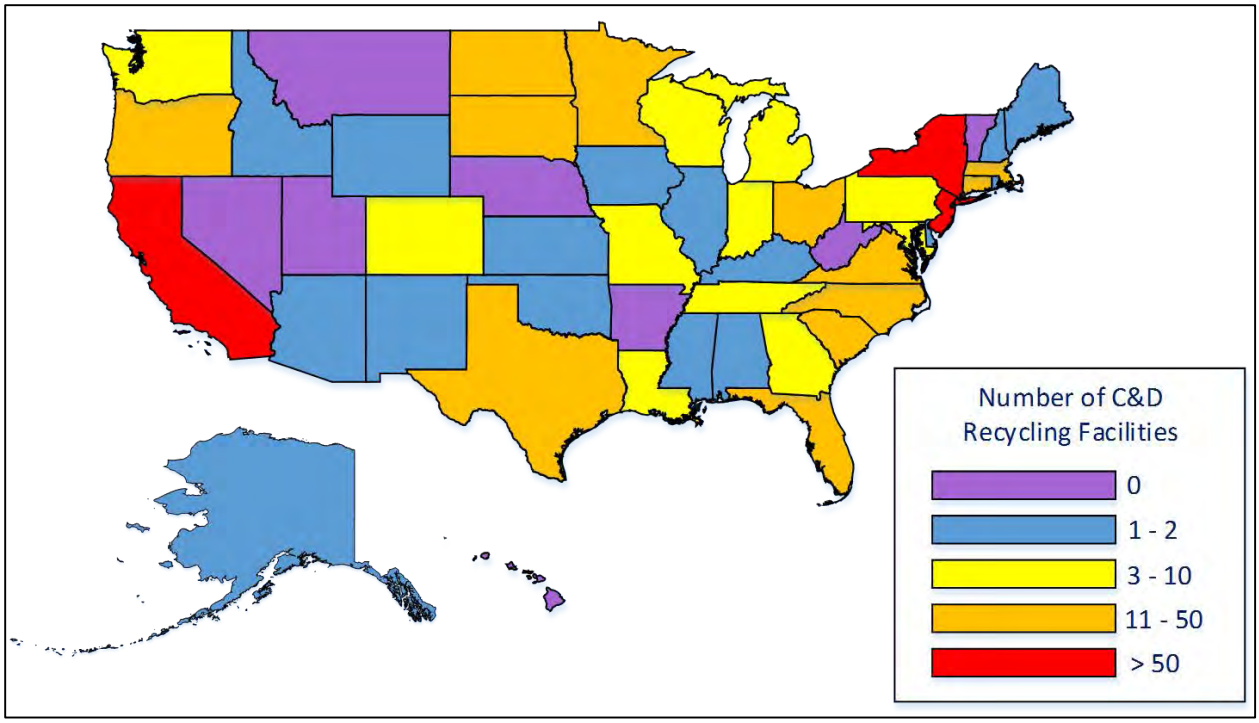

Figure 2-3. US Map Showing Grouped Distribution of the Number of Active C&D Recycling Facilities Based on State Databases, Direct Facility Contact, and WBJ (2012) as of 2012

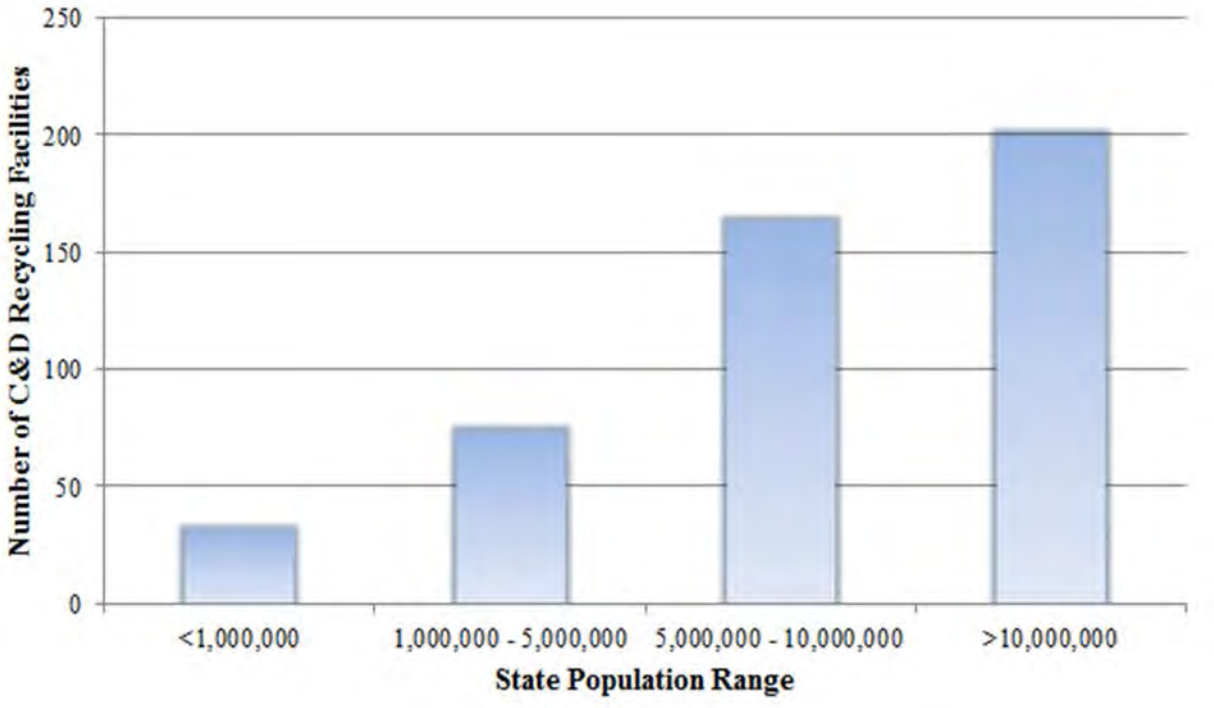

Figure 2-4. Distribution of the Number of C&D Debris Recycling Facilities as a Function of State Population

2.4 Discussion of State Regulations Review

The review of state regulations presented in Section 2.2 provided a range of information regarding the state of C&D debris management in the US, both in terms of how disposal facilities are regulated as well as how recycling and processing facilities are regulated. This section provides a series of figures and data summarizing the review of regulations. First, broad observations regarding the regulatory review are provided as follows:

- **Definitions**. Nearly all states had a specific definition for C&D debris. The definition of C&D debris varied, sometimes substantially, between states (e.g., some states excluded CESQG waste from the definition of C&D debris). A common approach to defining C&D debris included listing specific materials that are considered to be C&D debris. Another approach several states used included listing materials (which could originate from a construction or demolition site) as "clean rubble" or "clean debris," which was often coupled with regulatory language exempting these materials from management as a solid waste.
- **C&D Debris Regulations**. Most states have specific regulations pertaining to C&D debris disposal facilities, many of which include exclusively C&D debris, and in some cases there are broader waste classifications that include C&D debris. In contrast, many states (31) do not have regulations pertaining to the recycling and processing of C&D debris. In some cases, certain recycling activities like C&D processing fell outside of the definition of solid waste, thus recycling activities were exempted from solid waste regulations. In this case, recycled amounts are frequently not tracked, and these facilities are also often not subject to routine compliance inspections by the state. In other cases, states (10 total) had rules for waste processing and in these cases, a listing of wastes subject to the rule (which often included C&D debris) was given. In other cases, states (9 total) had specific C&D debris processing facility regulations.
- **Regulatory Flexibility**. In nearly all cases, states had regulations that provided flexibility in terms of stringency. For example, many states have provisions to allow requirements such as bottom liners and leachate collection systems to be conditional, which gives a site owner the opportunity to demonstrate that these systems are not needed based on site-specific factors. On the other hand, many states had language that provided the regulatory agency the ability to apply conditions that were more stringent if site-specific conditions warranted.

Specific aspects of state rules regarding construction and operational requirements were evaluated to assess broad trends. ***Figure 2-5*** depicts a classification of each state based on the regulatory minimum bottom liner and leachate collection system requirements. The data showed that 17 states require some form of liner and leachate collection system, while five states require a liner but no leachate collection system, 12 have explicit conditional requirements for liners (e.g., liners and leachate collection systems may be required for landfills that are a certain design size but not required for smaller sites), and 16 states have no minimum liner and leachate collection system requirements. Note that for many states, it was common for the regulations to include language giving the regulatory agency the authority to require more strict engineering controls if site conditions warrant.

The data in ***Figure 2-5*** were compared to the average annual precipitation in each state, which is depicted in ***Figure 2-6***. A broad comparison of these two figures appears to suggest that, in general, states that have higher levels of precipitation tend to have more stringent liner and leachate collection system requirements.

Figure 2-7 presents a map depicting the minimum groundwater monitoring requirements at C&D landfills in each state. Overall, 13 states have no minimum groundwater monitoring requirement, 11 have conditional requirements, and 26 have monitoring requirements. US EPA (1995c) indicated that as of the mid-1990s, 29 states require "some or all construction and demolition facilities" to monitor groundwater. Thus, using the same criteria that were used in US EPA (1995c), the number of states that currently

require some or all C&D debris landfills to monitor groundwater is 37, an increase of approximately 28%. The 26 states that require groundwater monitoring were further examined to assess the relationship to the number of C&D landfills in the state. ***Figure 2-8*** shows that the number of states that require groundwater monitoring is fairly evenly distributed across the different "landfill number" bin sizes. This suggests that the requirement to monitor groundwater is not heavily influenced by the number of facilities that would be required to comply with such a regulation.

The data in ***Figure 2-5*** was compared with the data in ***Figure 2-7*** to examine the overlap between states that require liners and leachate collection systems at C&D landfills and states that require groundwater monitoring at C&D landfills. ***Figure 2-9*** summarizes the results of this comparison. The data indicate that the greatest number of states (18) have a requirement for groundwater monitoring and a liner and/or a leachate collection system, whereas it was least common for a state to require a liner and/or a leachate collection system but no groundwater monitoring. A total of nine states were identified that had no minimum requirement for liners, leachate collection systems, and groundwater monitoring.

Figure 2-10 summarizes an assessment of the operational cover soil requirements in each state. The data shows a wide range of cover soil application frequency, ranging from no minimum requirement to daily. This finding is in contrast to the RCRA Subtitle D requirements for MSW landfills, which require the application of 6 in. of cover soil (or an approved alternative) daily. The application of cover soil at C&D landfills can have substantial implications with respect to several of the damage pathways examined in this report, including groundwater quality, the emission of H_2S, and occurrence and persistence of fires. These issues are described in more detail in Section 3 and Section 4.

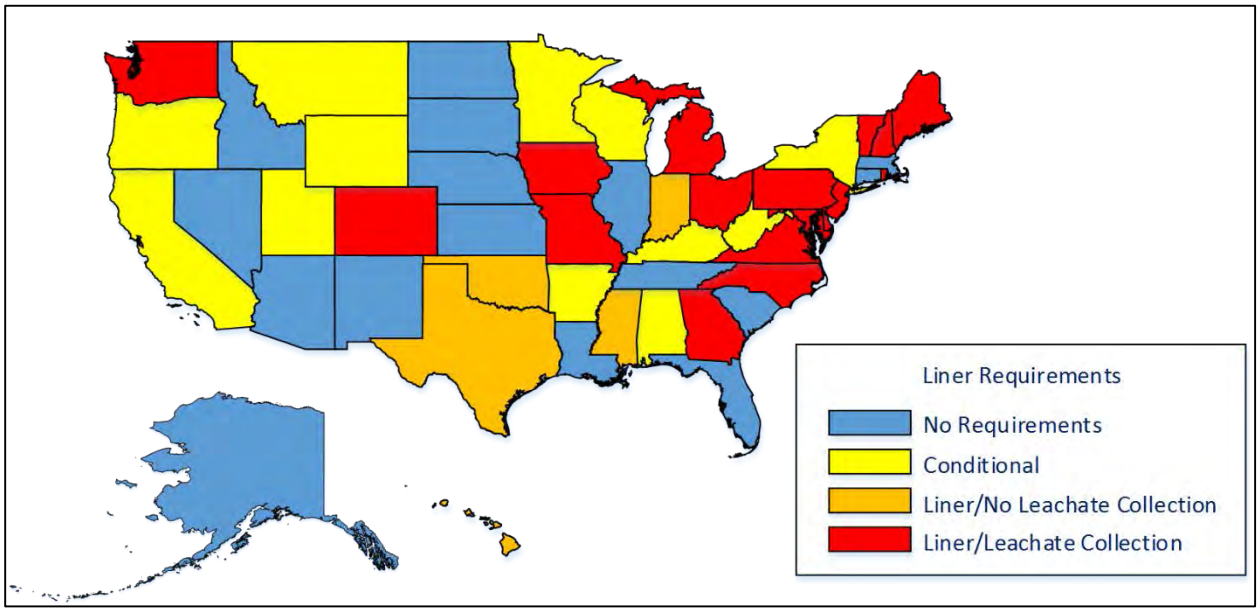

Figure 2-5. Summary of Minimum C&D Landfill Liner and Leachate Collection System Requirements in the US as of 2012

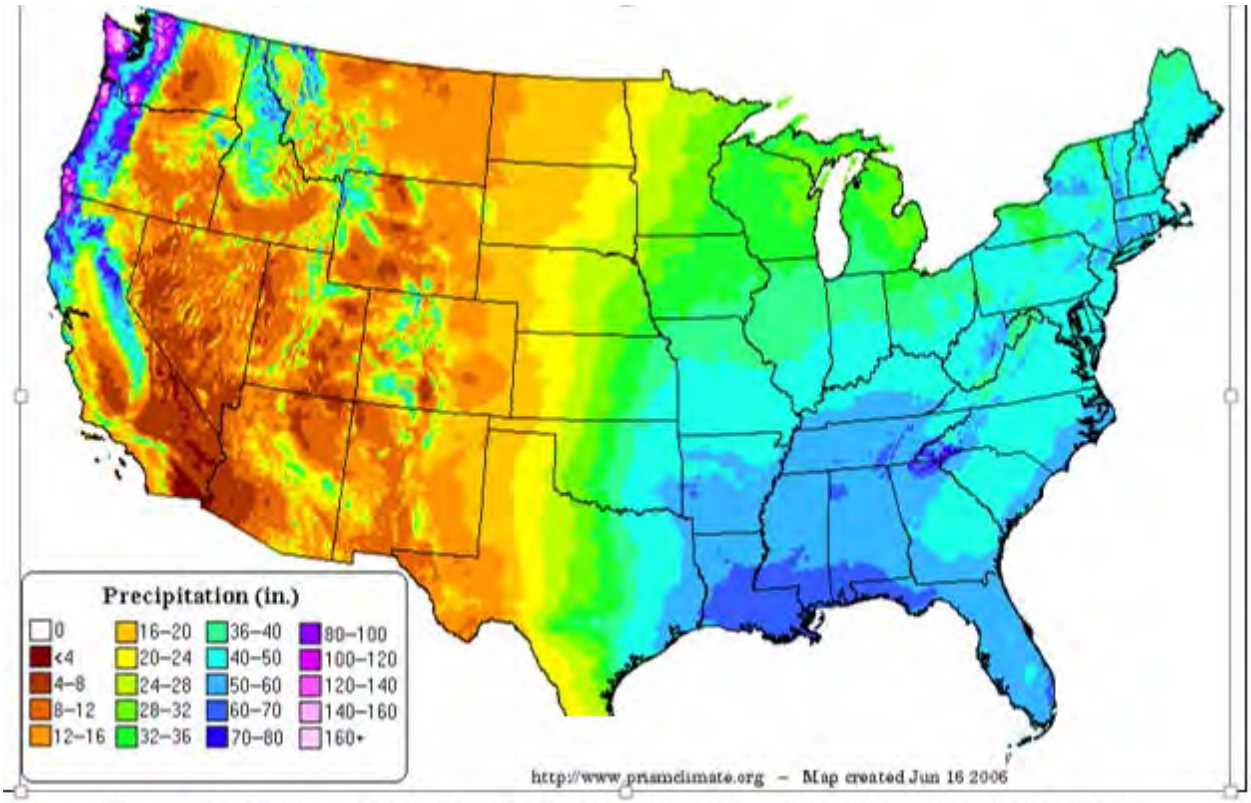

Figure 2-6. Average Annual Precipitation in the US From 1971 to 2000 (NOAA 2012)

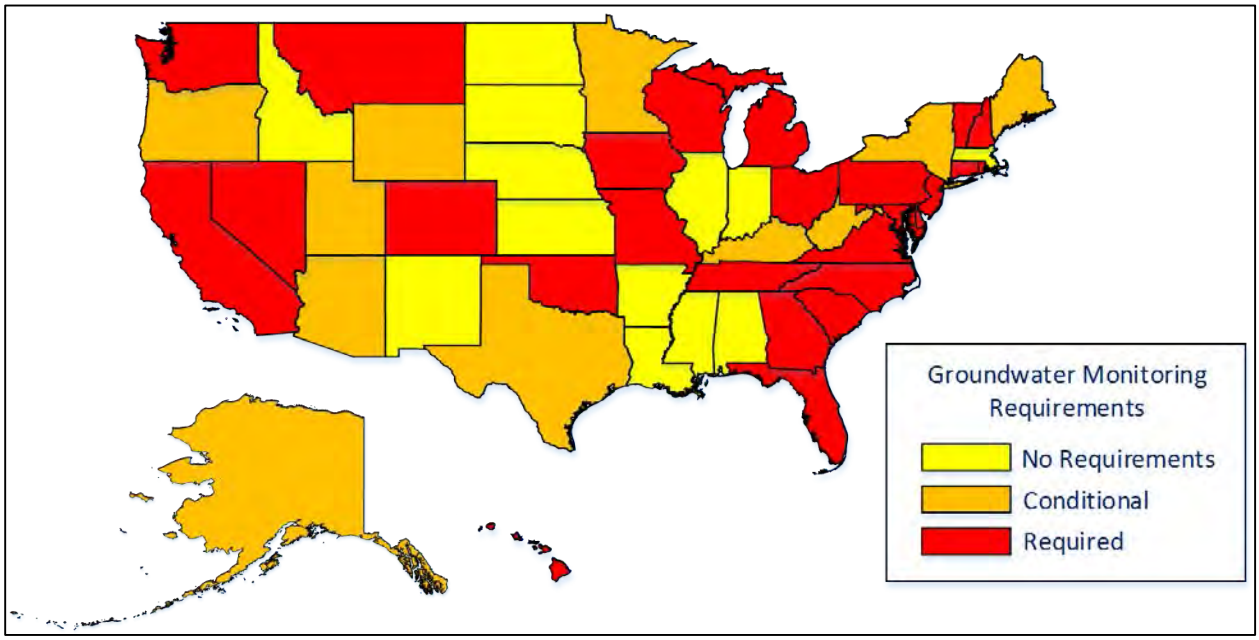

Figure 2-7. Summary of Minimum C&D Landfill Groundwater Monitoring Requirements Including Conditional Requirements in the US as of 2012

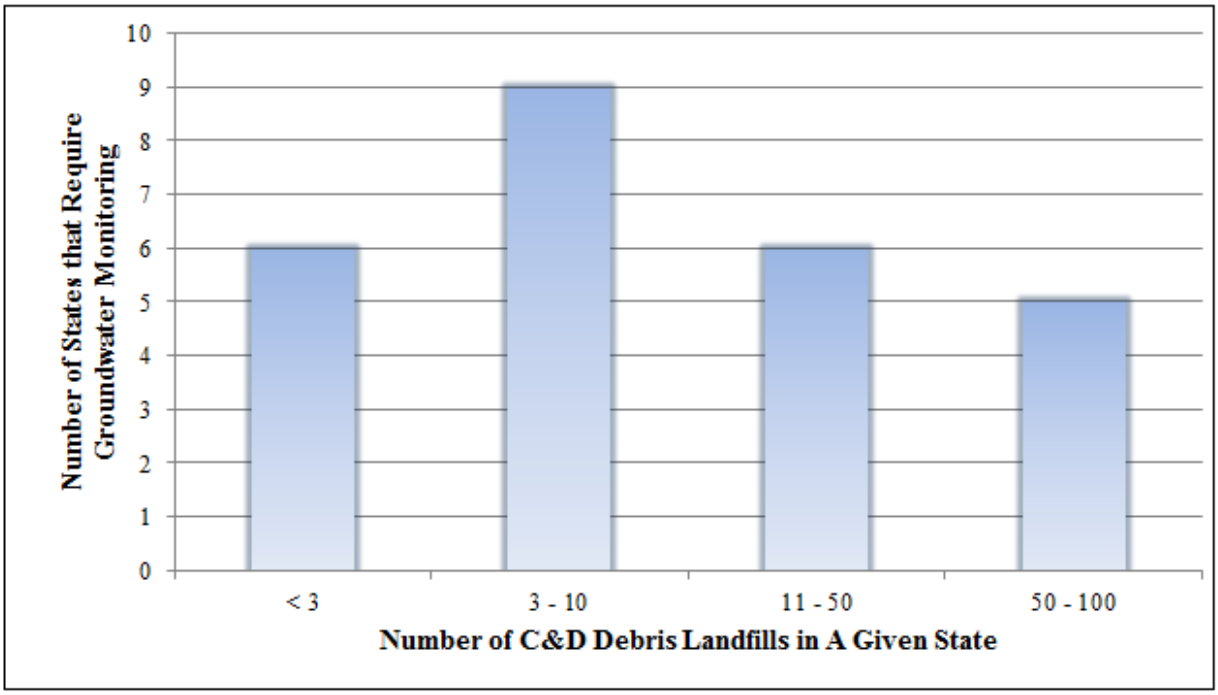

Figure 2-8. Comparison of States with Required Groundwater Monitoring at C&D Landfills and the Number of Landfills in a State

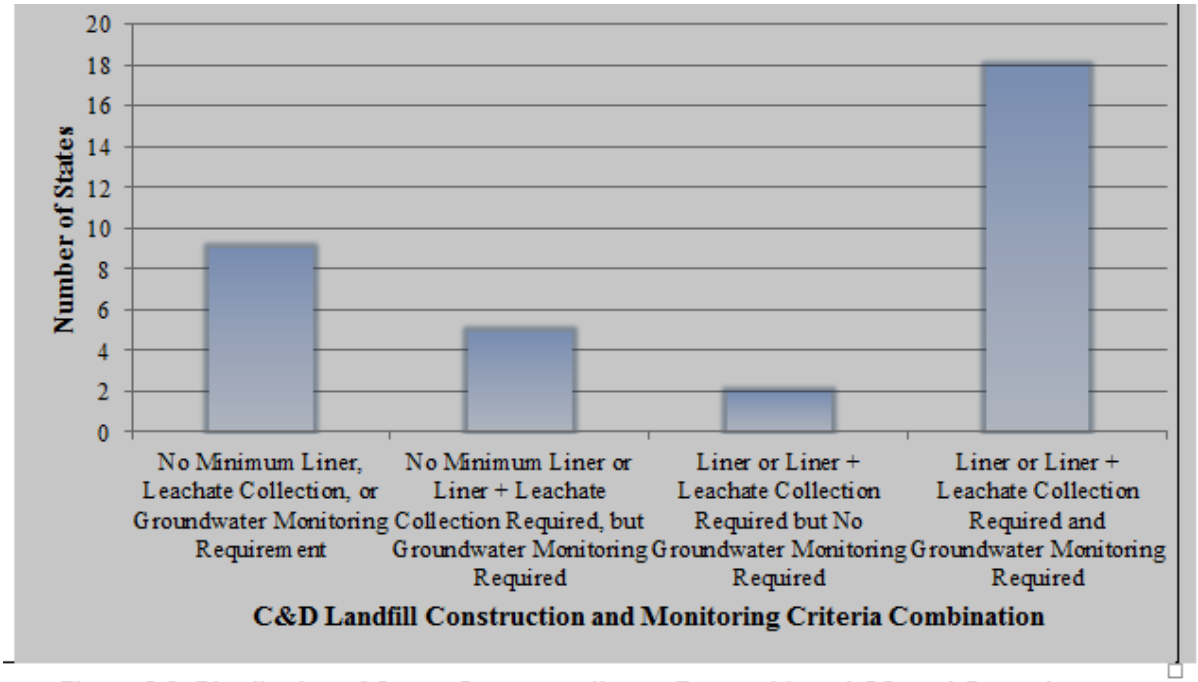

Figure 2-9. Distribution of States Corresponding to Bottom Liner, LCS, and Groundwater Monitoring Requirements in the US

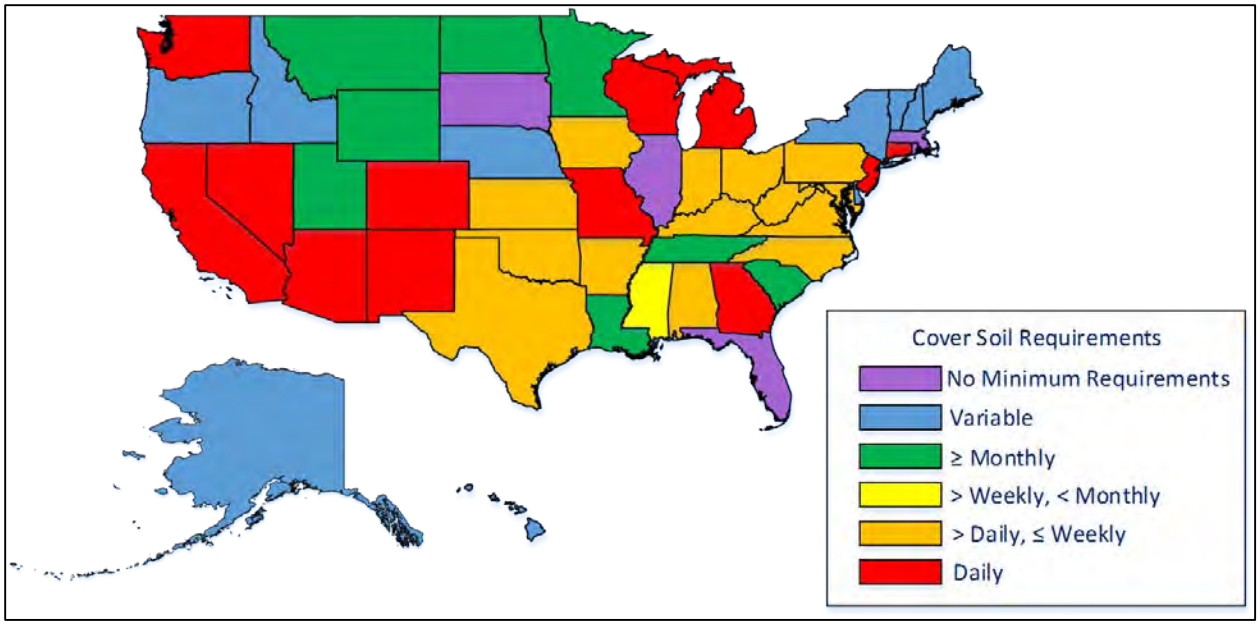

Figure 2-10. Summary of Minimum Operational Soil Cover Application Frequency for C&D Landfills in Individual States in the US as of 2012

2.5 Discussion of Identified Damage Sites

The project team took a multi-step approach to identify potential damage sites in each state. First, representatives from each of the 10 US EPA regions were queried regarding their knowledge of C&D debris damage sites. None of the US EPA regions identified knowledge of damage sites for facilities that only handle C&D debris, but the regional representatives all indicated that individual states would have more direct knowledge of site issues. Research regarding damage was then conducted by evaluating publicly available information from state solid waste databases as well as contacts with solid waste regulatory program personnel in each state. In all cases, state regulatory representatives located in the state's headquarters office were contacted.

In some cases, the regulatory representatives had knowledge of C&D damage sites and were able to furnish a list of facilities. In many cases, the state regulatory representatives contacted indicated that compliance and enforcement issues related to damage are handled at a district or regional level, and that district or regional representatives would have to be contacted to obtain additional information. In the queries to each state, the timeline under consideration for damage sites was limited to sites that currently or recently were identified as having damage, though no strict boundary was necessarily provided. In this analysis, the contact with states did not go beyond the headquarters level because of project time constraints.

A total of 44 damage sites were identified in 17 states located in eight of the 10 US EPA regions. ***Table 2-1*** summarizes the inventory of sites obtained using the methods described previously. The number of sites identified is expected to be less than the universe of actual damage sites for the following reasons:

- Several states (24) do not have minimum requirements for monitoring groundwater for all C&D debris landfills, so in those cases impacts to groundwater would be difficult to quantify due to the absence of monitoring data.
- Several states indicated that compliance and enforcement are handled at the regional or district level, thus a response of "no known damage" was indicated for several states. The response is more of a function of the way a given state structures its enforcement group, though, and not necessarily indicative that a state has no sites that would fit the profile of a damage site.
- Many states do not have rules specific to C&D debris processing facilities, and in other cases, recycling of C&D debris is an activity that is excluded from regulation under solid waste rules. Thus, in many cases, these facilities are often not permitted or inspected by state regulatory agencies.
- While a fairly narrow definition of "damage" was provided to the state representatives when developing the inventory, the subjectivity of the question could cause a varied response from a given representative based on their experience level and interpretation of terms like "recurrent" or "problematic."

Table 2-1. Summary of C&D Facility Damage Inventory Based on Queries to State Solid Waste Regulatory Personnel and Examination of Other Publicly Available Reports and Case Studies

State	Number of Damage Sites Identified
Arizona	3
California	1
Delaware	1
Florida	3
Georgia	6
Hawaii	1
Idaho	1
Kansas	1
Kentucky	3
Mississippi	4
Missouri	2
New Jersey	1
Ohio	8
Oregon	1
Rhode Island	1
Virginia	1
Wisconsin	6

3. Evaluation of Potential Damage from C&D Management and Statewide C&D Management Damage-Related Data

3.1 Overview and Methodology

This section discusses potential damage from C&D debris management facilities and an assessment of large-scale data sets collected at the state level. In contrast to the damage site inventory presented in Section 2, which reported damage sites based mostly on inquiries to solid waste regulatory staff (who in many cases were not directly involved with facility enforcement or compliance issues), the analysis in this section provides a more in-depth assessment of a handful of large data sets to identify broad trends and specific factors that may indicate environmental damage. The information analyzed in this section originated from the scientific literature (particularly that which has been conducted since the mid-1990s), statewide studies on C&D debris management conducted as part of rulemaking or guidance development (e.g., Maryland, Minnesota, and Ohio), and other readily available state-wide data sets (e.g., Wisconsin, Virginia, and Florida).

The information provided in this section does not necessarily represent an exhaustive list of all states that have conducted large-scale environmental impact or extensive compliance evaluations related to C&D debris, nor does it represent an exhaustive examination of all publicly available data sets for C&D debris facilities. The methodology of data set selection and collection was based on several factors, including the following (in decreasing order of importance):

- data set availability;
- data sets that included information on multiple facilities in a given state;
- data sets that included information on a variety of issues, including groundwater, odors/air emissions, and other operational issues; and
- varied geographic representation in the US.

The information that was gathered and analyzed for each state varied in terms of depth and breadth of information. In some cases, large data sets regarding permits, permit applications, compliance, enforcement, and monitoring data were available. In other cases, only raw data sets were available and follow-up with the regulatory agency occurred to check data completeness and provide context to the data. In all cases, the data that were examined in this section are from secondary sources (i.e., data collected and, in some cases, reported by others).

The summary of scientific literature regarding groundwater impacts, gas production, fires, and issues related to C&D debris recycling and recycled C&D debris components is provided in Section 3.2, while the examination of statewide data is presented in the remaining subsections.

3.2 Technical Discussion of Damage from C&D Debris Management Based on Recent Scientific Literature

The studies conducted by the US EPA in the mid-1990s related to damage at C&D disposal facilities focused mostly on groundwater impacts, with some acknowledgement of surface water impacts. As discussed, damage at C&D debris management facilities may be manifested in other ways, particularly with regard to air emissions as well as other issues such as fires. Even in the case of groundwater, a tremendous amount of research has been conducted since the mid-1990s that discusses issues with leaching of chemicals from major components of C&D debris (which is a concern, along with leaching of hazardous chemicals from other products that may be in C&D debris in trace amounts, such as paints, glues, and solvents). Furthermore, increased observation of odorous emissions, as well as increased

understanding of the mechanisms that cause odorous emissions, has occurred in recent years. Thus, prior to the more detailed discussion of damage related to the statewide studies (as well as the detailed damage cases presented in Section 4), it is important to discuss the different damage pathways as well as the potential human health and environmental impacts.

3.2.1 Groundwater impacts

Groundwater monitoring is conducted at C&D debris management facilities on a routine basis to evaluate groundwater quality. Upgradient and downgradient wells are used to compare data and draw conclusions regarding the data, in addition to site hydrogeologic conditions. The leaching of components into the groundwater may occur if no earthen or synthetic liner is present (or if the liner system does not function properly), and in some cases may depend on the constructed location of the site (e.g., proximity of the landfill bottom to the water table). Most newer facilities have detailed hydrogeological characterizations conducted prior to waste placement to provide groundwater quality baseline data and meet siting criteria. In some cases, groundwater quality has been shown to be impacted at facilities just because of the presence of the landfill itself and not as a result of direct leaching from the waste.

When no liner is present, leachate resulting from the contact of rainfall and C&D debris components has the potential to degrade water quality. While surface water can be impacted from leachate seeps from the side slopes or the base of the landfill, the more common concern is leachate migration through the landfill to the underlying aquifer. Bulk building materials such as concrete, wood, and drywall have been demonstrated to create leachate elevated in minerals content with a potential for causing groundwater concentrations at monitoring wells to exceed secondary water quality standards (Townsend et al. 1999, Weber et al. 2002, Jang and Townsend 2003). Other building debris components contain chemicals with known human health hazards, including lead (e.g., paint, metal sheeting), mercury (lighting, electrical switches), and PCBs (light ballasts, paints). Research has found that some elements in C&D debris (e.g., lead) may be largely contained within C&D debris landfill environments because of the tendency of the SO_4^{2-}-reducing environment to bind metals (Wadanambi et al. 2008).

Leaching from preservative-treated wood and the possible impact on groundwater quality at C&D debris landfills has been evaluated at length in the past 10 years (Weber et al. 2002, Townsend et al. 2004a). Chromated copper arsenate (CCA), which until recently was the predominant wood preservative used in the US, released arsenic in leaching tests and simulated landfills at concentrations that could result in water quality maximum contaminant level (MCL) exceedances in groundwater wells if sufficient dilution does not occur (Jambeck et al. 2008). Research on the predominant preservative replacements for CCA, a series of chemicals based primarily on copper, found that copper was largely contained within the C&D landfill environment, though other preservative chemicals, such as boron, continued to leach (Dubey et al. 2009).

Recent research has focused on the release of naturally occurring substances from soils and the aquifer matrix as a result of conditions induced by C&D debris landfill leachate (Wang et al. 2012). The phenomenon is known as reductive dissolution; iron and manganese oxide minerals are dissolved as bacteria consume organics in leachate, leading to elevated concentrations of these dissolved metals (in their reduced redox state) in groundwater (Lovley 1991; Heron and Christensen 1995). Additionally, the presence of a landfill itself (with or without a liner) may cut off surficial aquifer atmospheric oxygen exchange, thus leading to reducing conditions beneath landfills and thus causing reductive dissolution (Sarasota County 2010). Given that arsenic is often naturally bound to iron minerals, this phenomenon can lead to elevated groundwater concentrations of arsenic as well (deLemos et al. 2006).

3.2.2 Gas Production and Migration

Since the previous US EPA investigation of damage cases from C&D debris, several cases involving gas emissions from C&D debris landfills have been documented, which resulted in several studies on the issue. Hydrogen sulfide (H_2S) and other reduced sulfur gases have been documented to occur in large concentrations at C&D debris landfills (Eun et al. 2006, Lee et al. 2006), causing problems of both odor and nuisance to local residents, as well as potential health concerns to on-site workers and the surrounding community. Disposed gypsum drywall can cause the formation of H_2S in a landfill through the presence of a combination of factors including moisture, anaerobic conditions, and a carbon source. In the moist, anaerobic environment of a landfill, SO_4^{2-}-reducing bacteria utilize dissolved SO_4^{2-} from gypsum (hydrated calcium sulfate, $CaSO_4 \bullet 2H_2O$) drywall as an electron acceptor in the consumption of organic matter, producing H_2S. The kinetics of H_2S formation (Tolaymat et al. 2012) and the measurement of H_2S concentrations at operating landfill sites have been evaluated and reported (Xu et al. 2010a, Xu et al. 2010b). The emission of H_2S depends on weather conditions (e.g., atmospheric pressure, wind velocity, temperature) and the presence or absence of a cover soil and cap and associated characteristics, and the presence and/or performance of gas controls.

Laboratory experiments to replicate the formation of large concentrations of H_2S in simulated C&D debris landfill environments containing gypsum drywall have been conducted (Yang et al. 2006, Plaza et al. 2007). Recent research has focused on methods to control H_2S formation and to remove H_2S once it is produced (Xu et al. 2010a, Xu et al. 2010b). Removal of H_2S from C&D was evaluated by Xu et al. (2010a,b), who found that physical removal of H_2S from the gas phase can be accomplished with a variety of materials (e.g., concrete fines, mulch, native soil, and steel) with varying results. Other researchers have studied H_2S removal or mitigation using other cover amendments, such as metal oxides (Bergersen and Haarstad 2008) and waste biocover soil (He et al. 2011).

One facility in Ohio (as detailed in Section 4) was remediated under the US EPA Superfund program because of large emissions of odorous gases resulting from the disposal of pulverized gypsum drywall. As a follow-up to the remediation of this site, the US EPA (2006b) developed a guide to manage H_2S from landfills that accept pulverized gypsum drywall. Continued issues with H_2S emissions at C&D and MSW landfills elsewhere in the US have occurred since that time, and the US EPA recently commissioned an evaluation to develop a more comprehensive best management practices guide for preventing and controlling H_2S emissions from landfills that accept gypsum drywall (US EPA 2012).

3.2.3 Fires

Landfill fires can result from deposition of smoldering waste loads or by spontaneous combustion. Fires can cause hazards for on-site workers as well as emit multiple types of air pollutants. The physical nature of C&D debris differs from MSW in that many materials are bulky and rigid, thus while standard procedures at C&D disposal facilities involve the use of bulldozers and compactors to compress the waste, size reduction tends to be the primary mechanism for consolidation. Given the bulky nature of C&D debris, coupled with the fact that many C&D debris landfills have minimal or infrequent cover soil application requirements, conditions can occur where air voids form within the waste mass. Additionally, the formation of above-grade side slopes that are steep (e.g., greater than standard 3 horizontal to 1 vertical rise configuration) can result in air from prevailing winds entering the landfill, introducing oxygen and creating a chimney effect, which can contribute to or exacerbate fire issues. Formation of steep slopes also reduces the ability to compact the waste mass because of decreased normal forces exerted on the waste during compaction, which can further encourage the formation of air voids in the waste. The Federal Emergency Management Agency (2002) suggested that C&D landfills are more susceptible to a major landfill fire compared to other types of landfills.

Aside from the health and safety issues associated with a fire at a landfill, the occurrence of landfill fires at C&D debris facilities, as well as the steps to remediate them, can magnify other potential environmental concerns. For example, a common firefighting measure is the addition of water to the impacted area, but this can increase the quantity of leachate produced, and can also increase the moisture content of the waste, which can promote the production of H_2S (this issue was observed in the Florida damage case highlighted in Section 4). Also, the release of some chemicals may be enhanced from burned waste, such as arsenic leaching from the ashes of burned CCA-treated wood. Furthermore, the combination of fire and added water can create voids within the waste, thus creating paths for gases and leachate to short circuit through the landfill, which could result in uncontrolled releases to the environment.

3.2.4 C&D Debris Recycling

Limited research has focused on environmental issues associated with C&D recycling operations, particularly when compared to research on health and environmental concerns at C&D debris landfills. As described in Section 2, many states exempt certain C&D recycling activities from solid waste regulations, thus close examination of C&D recycling practices may not always be documented through compliance and enforcement activities.

Issues that may occur at C&D recycling facilities may include problems with the storage of certain materials. Several states with rules specific to C&D recycling place limits on the amount of time and/or the volume of recyclable material that can be stored prior to shipment off-site for ultimate use or further processing. An example where large amounts of debris were stockpiled and significant issues occurred (e.g., fires) is highlighted in the California damage case presented in Section 4. Other operational concerns that have been investigated involve the physical processing of debris at C&D recycling facilities. For example, concerns about the potential presence of asbestos (and therefore subsequent release following grinding or size reduction) in discarded asphalt shingles has been the subject of a substantial amount of research, but large-scale examination of operational data (e.g., as summarized by the Construction Materials Recycling Association [2007]) suggests that this concern is minimal, given appropriate sampling and material sourcing procedures.

The possible environmental concerns associated with the reuse of some products generated from C&D recycling operations have been evaluated. For example, the chemical content of recovered fines produced during the screening operation at C&D debris recycling facilities has been evaluated for organic chemicals (Jang and Townsend 2001a), heavy metals (Townsend et al. 2004b), and SO_4^{2-} (Jang and Townsend 2001b). Screened C&D fines, which are frequently utilized as cover soil and material for grading and shaping of slopes at C&D and MSW landfills, may also contain concentrations of SO_4^{2-} that can lead to the formation of H_2S, and some states (e.g., New Hampshire) have developed specifications for cover materials that limit the SO_4^{2-} content of screened fines (New Hampshire Department of Environmental Services 2004). Arsenic contamination of C&D debris wood mulch from recycling operations has also been evaluated (Tolaymat et al. 2000, Townsend et al. 2003).

3.3 Florida – Groundwater Monitoring Data at C&D Disposal Facilities

The Florida Administrative Code (62-701, FAC and 62-520, FAC) requires routine groundwater monitoring at C&D landfills in Florida. Bottom liners and leachate collection systems by rule are not required unless site-specific conditions, as determined by the FDEP, warrant the need for a liner and leachate collection system to be installed. C&D landfills are required to have at least one monitoring well hydraulically upgradient (background well) and at least two detection wells located downgradient within 50 ft from the edge of the landfill. Semiannual monitoring for a suite of parameters is required as specified in 62-701 and 62-520, FAC, and the number of wells and the associated monitoring parameters for each landfill are specified as part of the facility's permit conditions. The FDEP maintains a database

of water quality monitoring data submitted by operating facilities at a frequency specified by the facility's permit. The data for 91 C&D debris landfills were downloaded and analyzed to examine trends related to measured chemical constituents to assess on a broad basis if or how groundwater at C&D landfills is being impacted in Florida.

The project team downloaded groundwater data for all of the facilities classified as C&D landfills and compiled the data in an MS Access database; 121 facilities were classified as C&D landfills, of which 91 were found to exclusively accept C&D debris (30 facilities also allowed the acceptance of MSW and/or Class III waste, which includes other non-putrescible, non-C&D debris). Only the 91 facilities that accepted only C&D debris were analyzed further.

3.3.1 Data Analyzed

The database included more than 450,000 measurements of more than 400 chemical constituents, including field parameters and inorganic and organic compounds, for the 91 sites. Data for each site represent monitoring events as early as the mid-1990s and as recently as 2011. The number of years of data available for each site varied based on availability in the database.

As part of routine landfill compliance, groundwater monitoring events are conducted in accordance with a site's permit, and the resulting measured concentrations are compared to appropriate target levels, which are based on federal MCLs (primary and secondary) or risk-based target levels. ***Figure 3-1*** presents the total number of measurements and the number of measurements (includes all measurements, upgradient and downgradient) below the respective laboratory detection limit and above the Florida Groundwater Cleanup Target Level (GCTL) either in mg/L or µg/L.

More than 95% of the measurements of organic compounds were below the corresponding laboratory detection limit. Approximately 28%, 13%, and 1% of field parameters and inorganic and organic compound measurements were detected at concentrations greater than the respective GCTL.

A total of 60 organic compounds exceeded the GCTL at least once. The organic compounds measured at more than 10 sites that exceeded their GCTL in more than 1% of measurements were: acrylonitrile, aldrin, benzene, bis (2-cloroisopropyl) ether, bis (2-ethyhexyl) phthalate, bromodichloromethane, cyanide, dibromochloromethane, methylene chloride, phenols, 1,1,2,2-tetrachloroethane, and vinyl chloride. Approximately 8.6%, 3.6%, 19%, and 5.3% samples exceeded the GCTL for benzene, bromodichloromethane, phenols, and vinyl chloride, respectively.

Of the 78 inorganic parameters that were detected, 43 exceeded the GCTL at least once. Iron, aluminum, arsenic, sodium, chloride, sulfate, thallium, and TDS most frequently exceeded the GCTL; these parameters were measured at concentrations greater than the GCTL at approximately 55 sites. ***Figure 3-2*** presents a comparison of the distribution of parameters (those that most frequently exceeded the GCTL) measured in upgradient and downgradient wells. In the box plot in ***Figure 3-2***, the line in the center represents the median concentration, the edges of the box represent the 25th and 75th percentiles of the data, and the edges of the whiskers represent the 10th and 90th percentiles of the data, with the remaining individual points representing outliers. As can be seen in ***Figure 3-2*** the median of concentrations measured at downgradient wells is approximately 2 to 4 times greater than that of upgradient wells for these parameters. The data also show multiple data points that fall outside of the 10th and 90th percentile of the data, suggesting a degree of scatter including low and high measured concentrations.

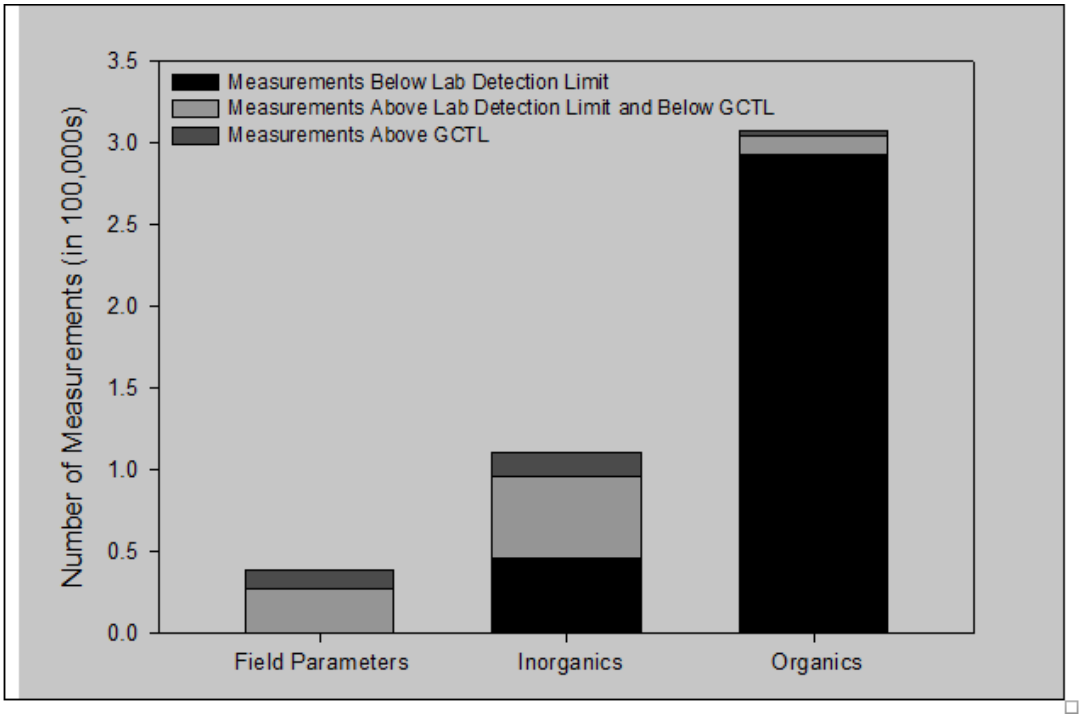

Figure 3-1. Summary of Broad Statistical Results Comparing Measurements of Field Parameters, Inorganic Compounds, and Organic Compounds to GCTLs from Groundwater Monitoring Data from C&D Landfills in Florida

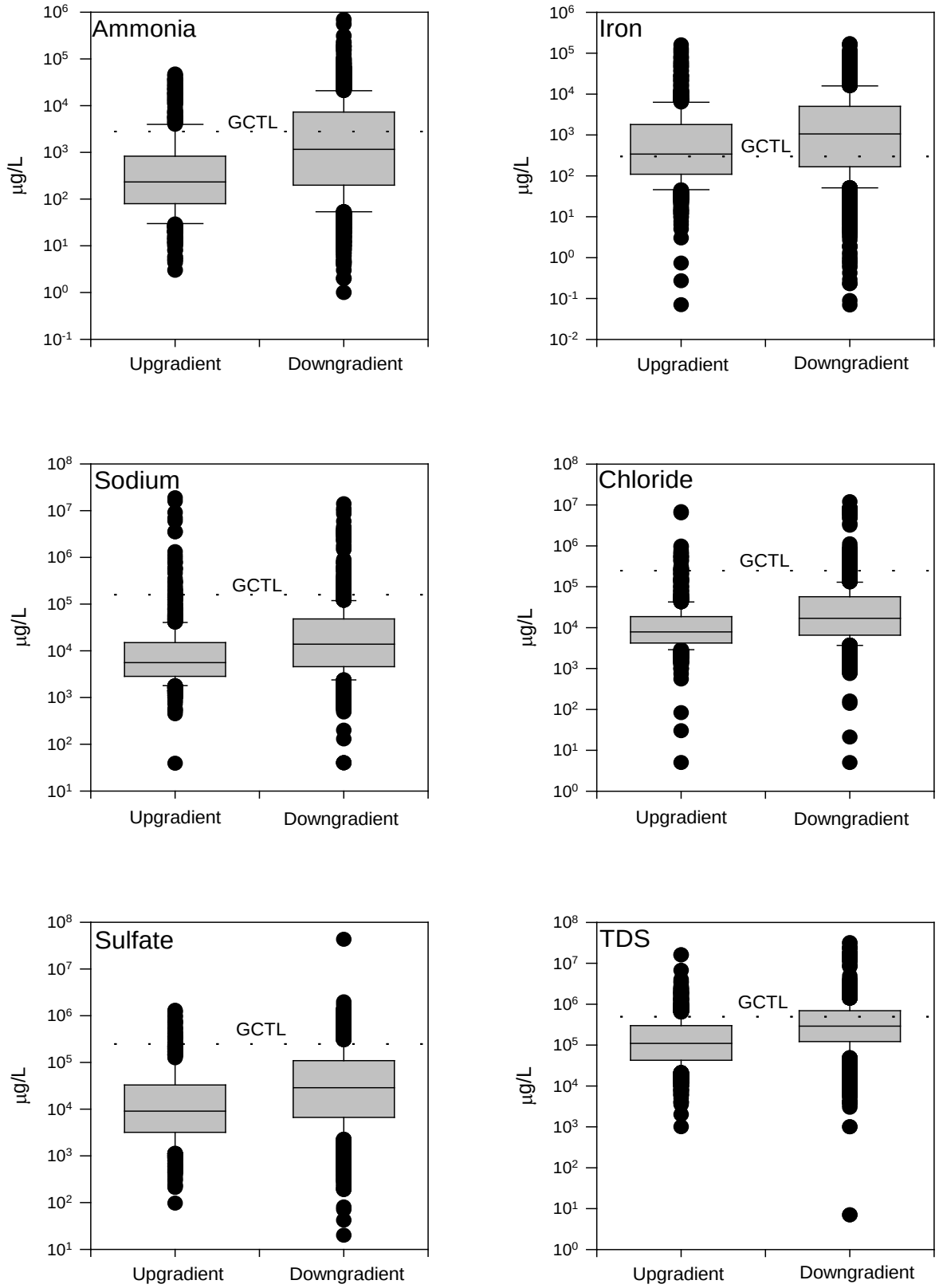

Figure 3-2. Comparison of Concentration Distribution of Selected Parameters for Upgradient and Downgradient Wells for C&D Landfills in Florida

Figure 3-3 presents a summary of detected constituents in groundwater at Florida C&D landfills that exhibited an exceedance of a GCTL at least once in a downgradient well. The data indicate that iron, aluminum, phenols, TDS, arsenic, and ammonia showed at least one exceedance at a downgradient monitoring well at more than half of the 91 landfills analyzed.

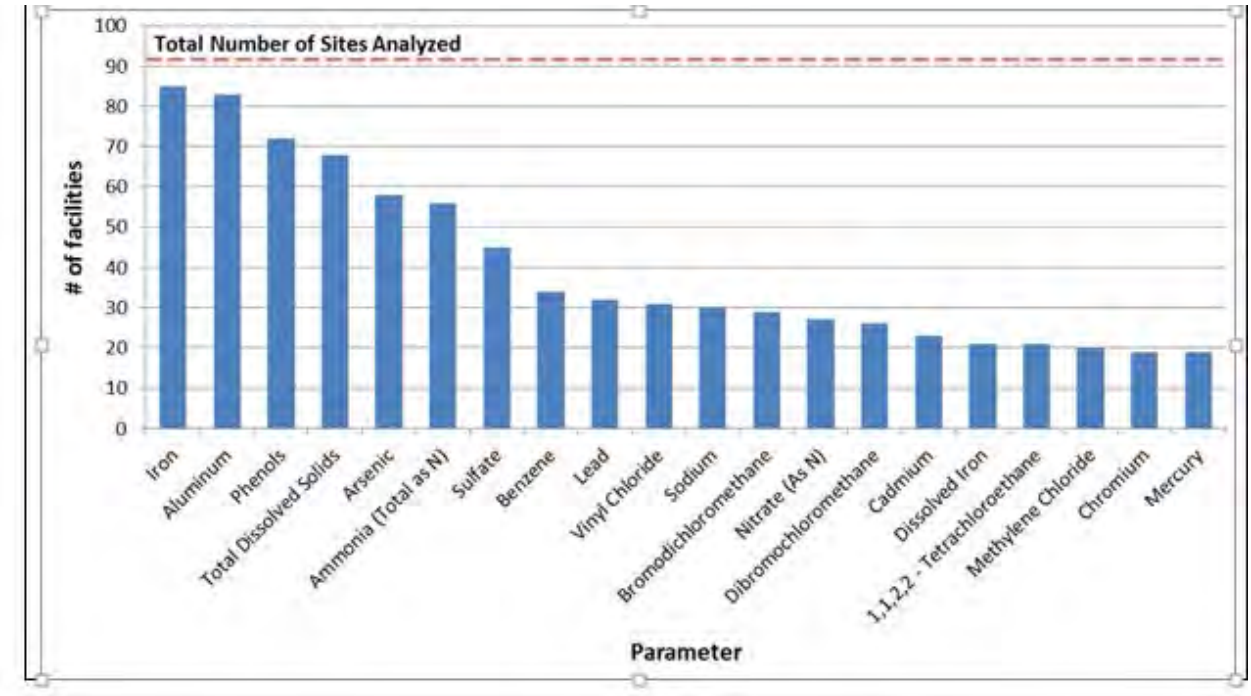

Figure 3-3. Summary of the Number of Facilities That Exhibited at Least One Exceedance of a GCTL at a Downgradient Monitoring Well, Organized Based on Chemical Constituent

Table 3-1 provides summary statistics regarding measured parameters in groundwater that exceeded the GCTL in downgradient wells. The data shows that aluminum, ammonia, dibromochloromethane, iron, phenols, and TDS exhibited elevated concentrations (when comparing the median concentration to the GCTL in downgradient wells) at several sites (>10).

Table 3-1. Summary of the Median Concentration of Measured Parameters in Groundwater that Exceeded the GCTL in Downgradient Wells

Parameter	Number of Sites with Downgradient Well Measurements	# of Sites with Median Concentration of Downgradient Wells > Upgradient Wells	# of Sites with Downgradient Median Concentration Exceeding GCTL
Aluminum	87	32	30
Ammonia (Total as N)	88	55	17
Arsenic	87	23	0
Benzene	88	13	1
Bromodichloromethane	88	11	8
Cadmium	87	9	0
Chromium	88	24	0
Dibromochloromethane	88	8	27

(continued)

Table 3-1. Summary of the Median Concentration of Measured Parameters in Groundwater that Exceeded the GCTL in Downgradient Wells (continued)

Parameter	Number of Sites with Downgradient Well Measurements	# of Sites with Median Concentration of Downgradient Wells > Upgradient Wells	# of Sites with Downgradient Median Concentration Exceeding GCTL
Dissolved Iron	28	12	15
Iron	89	51	47
Lead	89	11	0
Mercury	87	12	0
Methylene Chloride	88	16	0
Nitrate (As N)	88	32	0
Phenols	86	18	42
Sodium	89	62	1
Sulfate	88	58	3
Total Dissolved Solids	89	62	24
Vinyl Chloride	88	16	0

3.3.2 Data Analysis Summary

The data gathered and analyzed as presented in ***Figure 3-2***, ***Figure 3-3***, and ***Table 3-1*** suggest that groundwater impacts have occurred at several C&D landfills in Florida based on the broad comparison of upgradient and downgradient well measurements as well as comparison of downgradient measurements to applicable risk target levels. Note that a large amount of data was compiled and aggregated to provide broad summary statistics – the intent was not to conduct a rigorous risk analysis at the facility level. The data also indicate (based on the frequency analysis presented in ***Figure 3-3***) several organic and inorganic parameters, some of which are consistent with constituents of concern identified in the previous US EPA (1995b) damage case evaluation, and several others that were not.

The direct interpretation of the aggregated data in this analysis is subject to certain limitations. For example, grouping measured concentrations of several wells at a given site could overrepresent or under-represent potential impacts, depending on the magnitude of constituent concentrations measured and the number of wells in a given category (upgradient or downgradient), among other factors. The specific magnitude of impacts, though, and confirmation of whether a C&D landfill site is impacting the surrounding environment to the degree that it is acknowledged as a damage case, is an exercise that must be conducted at the facility level. A more detailed analysis of factors such as site-specific hydrogeology, operating practices, and other factors would need to be accounted for in such an assessment.

3.4 Maryland – Unauthorized Waste Acceptance and Leachate and Groundwater Quality at Rubble Landfills

Maryland Department of the Environment (MDE) is the regulatory body for Maryland's C&D landfills (defined in Maryland rules as rubble landfills). In the 1990s, research regarding operation and monitoring data at rubble landfills in Maryland was conducted as part of justification for modifications to the state's minimum design and operating requirements at rubble landfills. The proposed rules included a requirement to design and construct a low-permeability bottom liner system and leachate collection and

removal system. The state regulations prior to the proposed liner regulations were based on two assumptions: that debris that is allowed in rubble landfills is not expected to negatively impact the environment, and that debris that is prohibited from disposal in rubble landfills is not received in practice at rubble landfills. The information presented in this section was taken from a series of memoranda written by MDE (1997a).

3.4.1 Prohibited Waste Evaluation Review

MDE initiated a study to examine the procedures followed by permitted rubble landfills in the state related to compliance with promulgated waste prohibitions at the facility level. Several years of inspection records were reviewed and the results were as follows:

- Incidences of prohibited waste acceptance were present, even with in-place operational procedures to screen such wastes out.
- Between 1990 and 1997, approximately 44% (8 of 18 rubble landfills in the state) had at least one instance where unauthorized or prohibited waste was accepted.
- At least 32 instances of prohibited waste acceptance occurred between 1990 and 1997. Examples of prohibited wastes accepted included contained petroleum products and MSW.
- Another limited study at one rubble landfill in 1992 showed that three out of 20 loads (15%) contained greater than a de minimis quantity of MSW.
- The instances described only represent cases where an MDE inspector was on site and observed the prohibited waste acceptance.

3.4.2 Groundwater and Leachate Data Review by MDE in the Mid-1990s

In addition to operational history, MDE compiled leachate and groundwater quality data from several rubble landfill sites in 1997. Analytical data were summarized from eight rubble landfills; results included analytical data for collected leachate, leachate seeps (collected from side slopes or near active filling areas), and site groundwater. Major observations reported by MDE (1997a) are presented in ***Table 3-2***.

Table 3-2. Summary of Groundwater and Leachate Data for Rubble Landfills Analyzed by MDE (1997a) in the Mid-1990s

Site Number	Media	VOCs Detected	Non-VOCs Detected	Details/Discussion
1	GW	Freon 12, Chloroethane, Methylene chloride, 1,1,1,-Trichloroethane (TCA), Toluene, Tetrahydrofuran, Acetone, and various alcohols	—	Attributed to historical acceptance of auto parts
2	GW, Leachate	GW: Trichloroethene (TCE); cis-1,2-Dichloroethane above MCL Leachate: Freon 12, Freon 11, and Tetrahydrofuran	—	Leachate observed in a side seep
3	Leachate	Below MCL: Toluene, Freon 11, Xylenes, Benzene, Ethyl benzene and Methylene chloride Above MCL: Vinyl chloride	—	Measured in a leachate seep (1987)
4	Leachate	Freon 12, Freon 11, Methylene chloride, Chloroethane, 1,2-Dichloroethene, 1,2 Dichlorethene, 1,1,1-Trichloroethane (TCA), Trichloroethene (TCE), Tetrahydrofuran, and Acetone	—	Measured in leachate seeps (1986 – 1989)

(continued)

Table 3-2. Summary of Groundwater and Leachate Data for Rubble Landfills Analyzed by MDE (1997a) in the Mid-1990s (continued)

Site Number	Media	VOCs Detected	Non-VOCs Detected	Details/Discussion
5	GW	Freon 11, Freon 12, Methylene chloride, 1,1-Dichloroethane, Trichloroethene (TCE) and Toluene	—	—
6	GW	Below MCL: 1,2-Dichloroethene, Xylene Above MCL: TCE, vinyl chloride	—	Data from 1992 and 1993
7	GW	Tetrachloroethene, Trichloroethene, Freon 12, Chloroethane, and cis 1,2-dichloroethene	—	Data from 1990 and 1991; trace levels detected
8	GW	VOCs detected, but no specific chemicals listed	Lead	—
9	Leachate	Vinyl chloride (45 parts per billion (ppb)) and TCE (14 ppb)	Iron, manganese, sulfate, total dissolved solids	Data from lined C&D cell with leachate collection; data from 4 sampling events from 1996 - 1997

The results of the analysis conducted by MDE in the mid-1990s provided the justification for requiring rubble landfills to be lined in the state. Recommendations that were made during hearings as part of the rulemaking included proceeding with the requirement for liners and leachate collection systems, which was based on the following (MDE 1997b):

- Evidence from other studies conducted in the US (US EPA 1995a, US EPA 1995b) that suggested elevated chemical constituents in groundwater can occur at unlined construction debris landfills.
- The presumption that rubble waste (as defined in the Maryland solid waste rules) was inert was identified as false, a conclusion based on data collected by MDE personnel and operating facilities.
- Data collected in groundwater samples at operating facilities showed that groundwater impacts had occurred.

3.4.3 Review of Rubble Landfill Groundwater Evaluation Memos Written by MDE Since the Late 1990s

MDE furnished copies of internal memoranda that are developed by MDE staff upon review of routine groundwater monitoring data at C&D landfills. Memoranda for 11 active C&D landfills sites were provided with summaries that spanned approximately 10 years from 1999 to 2011. These documents generally described MDE staff interpretation of groundwater data and indicated parameters that were elevated (when comparing a downgradient well concentration with an upgradient well concentration) and above an applicable standard. Detailed statistical analysis was not conducted on the information in each memorandum because of limitations of source data, but in general the information for each of the 11 landfills did not suggest that significant impacts to groundwater were occurring, and that cases where recurring exceedances of applicable standards were either unresolved, attributed to poor regional groundwater quality, or identified as caused by the landfill but remedial actions were taken to address the issue. Evaluation of the information in these memoranda, when compared to information gathered by MDE in the mid-1990s as part of rulemaking requiring liners and leachate collection systems at rubble landfills, suggests that groundwater quality impacts at rubble landfills has declined since the promulgation of the liner and leachate collection system rules.

3.5 Minnesota – Groundwater Quality at C&D and Demolition Landfills

The Minnesota Pollution Control Agency (MPCA) produced a study on groundwater monitoring data collected at 43 demolition landfills in Minnesota, eight of which only accepted demolition debris (MPCA 2003). The MPCA (2003) document provided summary statistics for 43 demolition landfills, which included landfills that accept demolition waste only, accept demolition and industrial waste, and accept demolition, industrial waste, and MSW. The report did not allow for the differentiation between those sites that accepted only demolition debris and the other two types of facilities, but it is noted that the 43 landfills analyzed appeared to consist of unique cells (i.e., the site was either only demolition debris, or had a demolition debris cell in addition to MSW cells).

The purpose of the study was to conduct a statistical analysis on historical groundwater monitoring data and to evaluate whether groundwater was being impacted by the landfill. The study used a null hypothesis that stated upgradient and downgradient groundwater concentration should be equal – in cases where the null hypothesis was rejected (i.e., the data suggested, based on the Kruskal-Wallis one-way analysis of variance test with a $p < 0.05$, that there was a statistical difference in upgradient and downgradient wells), the data were further analyzed by site hydrogeologists to interpret the data and results. Measured concentrations were further examined through comparisons to state ILs and water quality standards.

A total of seven demolition-only landfills had data sets that could be used in the statistical analysis, and of these, five of the demolition landfills indicated groundwater impacts as measured at downgradient wells. Additional summary statistics from the analysis are as follows:

- Two of the seven demolition landfills had statistically significantly greater VOC concentrations in downgradient wells compared to upgradient wells.
- Four of the seven demolition landfills had statistically significantly greater inorganic constituents that exceeded health-based standard, and three had constituent concentrations that exceeded non-health-based standards.
- The most commonly detected VOCs were chlorofluorocarbons.
- The most commonly detected metals and metalloids were calcium, magnesium, sodium, potassium, iron, and manganese.
- The most commonly detected non-metal or metalloid inorganic constituents were sulfate, nitrate, chloride, and TDS.

Ultimately, the MPCA concluded that demolition landfills have the ability to impact groundwater. This led to the development of a state guidance document that provided a series of considerations and measures intended to provide more consistency during the siting and overall operations and management process for demolition landfill sites (MPCA 2005). Included in the MPCA guidance was the development of a three-tier demolition landfill classification system, which allows for varying construction and operation requirements depending on the quantity and nature of waste accepted at the site. ***Table 3-3*** provides a summary of the three-tier classification system.

Table 3-3. Demolition Landfill Classification System Developed as Part of MPCA Guidance (MPCA 2005)

Parameter	Demolition Landfill Classification		
	Class I	Class II	Class III
Site Evaluation	All sites will need to conduct a site evaluation to verify that location standards are met, soils are evaluated, depth to the water table is identified, and groundwater flow direction is defined.		
Acceptable Wastes	From an "Acceptable C&D Waste List"	From an "Acceptable C&D Waste List" plus non-recyclable packaging and demolition-like wastes (e.g., wood, concrete, porcelain)	All C&D Wastes plus most Industrial Wastes
Waste Screening	Stringent screening required.	Screening required.	Screening required.
Groundwater Monitoring	Determined based on depth to water table and underlying soil type.	Yes	Yes
Liner	No	Determined based on depth to water table, underlying soil type, and possibly modeling results.	Yes
Reclassification	N/A	If the facility accepts >50% industrial waste based on annual gate receipts, it should be reclassified as an industrial landfill.	

In 2008, the Minnesota Legislature passed a bill that required a work group to advise the Legislature on the management of C&D debris and industrial wastes, largely as a result of several factors including the MPCA's rules and guidance regarding the management of C&D and industrial waste landfills, and historical groundwater impacts in some areas of Minnesota (Construction, Demolition, and Industrial Landfill [CDIL] Work Group [2009]). The Legislature also imposed a moratorium on the siting of new landfills, pending the adoption of new rules from the MPCA regarding groundwater sensitivity and financial guarantees at landfills.

The CDIL Work Group developed a report in 2009 that had several recommendations, including the continued use of the demolition classification system (as shown in ***Table 3-3***) before being incorporated into eventual rulemaking. The CDIL (2009) document also pointed out that PBR demolition landfills in Minnesota (as described previously in Section 2) are not required to be monitored and recommended a groundwater evaluation study to assess the impact that PBR demolition landfills have had on groundwater quality.

3.6 Ohio – Leachate and Groundwater Quality at C&D Landfills

Two large-scale studies were conducted by the Ohio Environmental Protection Agency (OEPA) regarding environmental monitoring data collected at C&D landfills in the state. In 2005, the Ohio General Assembly required the OEPA to revise C&D debris disposal regulations, and in response to extensive comments received after draft rules were developed, the OEPA conducted a study to evaluate leachate quality data from C&D landfills where data were available and compared the data to that measured from MSW landfills in the state. A second study was conducted by OEPA (2011a) involving the examination of groundwater monitoring data at C&D debris landfills in Ohio to understand potential impacts in support of both previously promulgated rules related to liners and leachate collection systems at C&D debris landfills (OAC chapter 3745-400) and draft rules OAC chapter 3745-520.

3.6.1 C&D Landfill Leachate Study (2009)

Available leachate monitoring data from 30 landfills in Ohio were examined and compared to MSW landfill leachate data to evaluate the potential effects of the release of C&D debris leachate into the environment.

A total of 10 organic and 15 metals and other inorganic parameters were observed in both MSW and C&D leachate in similar quantities. Eleven parameters were not detected, and 14 parameters were detected with no difference in prevalence between the C&D and MSW landfill leachate. The leachate from all 30 C&DD landfills had three to 29 parameters with measured concentrations of water quality parameters that exceeded health based standards, surface water quality standards, or both. Health-based standards were exceeded for 18 organic and 15 inorganic parameters in C&D debris leachate, compared to 19 (organic) and 14 (inorganic) exceedances in MSW leachate. ***Table 3-4*** summarizes the parameters that were detected in similar quantities in C&D and MSW landfill leachate.

Table 3-4. Summary of Chemical Parameters Measured in Similar Concentrations in C&D Landfill Leachate and MSW Landfill Leachate at Facilities in Ohio (OEPA 2009a)

Leachate Monitoring Parameters Measured in Similar Concentrations in C&D and MSW Landfills		Leachate Monitoring Parameters Measured at Higher Concentrations in C&D Landfills Than MSW Landfills
Antimony	Arsenic	Calcium
Chromium	Cobalt	Copper
Iron	Nitrate-Nitrite	Magnesium
pH	Selenium	Manganese
Vanadium	Zinc	Sulfate
2-Butanone	4-Methyl-2-Pentanone	
1,4-dichlorobenzene	methylene chloride	

Four of the five parameters that were measured in higher concentrations in C&D landfill leachate were also parameters of interest in the hydrogeologic study described below. The study concluded that both types of leachate (C&D and MSW) are of concern to public health and the environment if released to groundwater and surface water, and that one was not necessarily less harmful or cleaner than the other.

3.6.2 Hydrogeologic Study of C&D Landfill Groundwater Data (2011)

The hydrogeologic study examined groundwater monitoring data from a total of 99 C&D landfill sites. Of the 99 sites evaluated, a total of 47 were considered to have substantially complete data sets that were used for additional analysis – the OEPA considered the following when assessing whether a site had a complete data set (OEPA 2011a):

- documented groundwater monitoring information/data;
- groundwater monitoring data including an analysis of key constituents over multiple sampling events;
- information related to C&D debris placement in the facility;
- identified or estimated separation distance from the debris liner to the first continuous zone of saturation (CZS)/uppermost aquifer system; and
- characterization of geologic/hydrogeologic conditions at or near the facility.

In the 2011 hydrogeologic evaluation report, indications of groundwater contaminant release were marked by evaluating background and downgradient groundwater quality, cases of increasing trends in a

constituent's concentration, and/or the presence of VOCs in downgradient wells(s). Reported indications of contaminant release were not regarded as confirmed releases. Of the 47 facilities with substantially complete data sets, 60% of facilities displayed indications of groundwater quality impacts. Commonly observed parameters included sulfate (20 sites), chloride (15 sites), ammonia (15 sites), potassium (15 sites), sodium (13 sites), magnesium (11 sites), and calcium (11 sites). Groundwater impacts were more likely to be observed at sites with lesser distances between the landfill bottom and the first CZS; 86% of sites with a separation distance of 5 ft or less had indications of groundwater impacts. No indications of impact were observed at any site with a complete data set where there was a distance of greater than 10 ft to the CZS.

Sensitive hydrogeologic settings (100 gal/min aquifer systems as designated by OAC), noted as areas with thick glacial sand and gravel deposits, karst areas, shallow fractured bedrock, and location within an old quarry (sand and gravel, limestone, sandstone), were also found to play a role in indication of contaminant release. Of sites with complete data sets, 81% located in sensitive hydrogeologic settings (25 sites, all with distances of between the water table and landfilled waste of <15 ft) showed indications of groundwater impacts; alternatively, only 35% of sites with no indication of groundwater impact are located in sensitive hydrogeologic areas. The presence of a bottom liner or leachate collection system (engineering protection) appeared to mitigate groundwater impacts; of sites with complete data sets showing impacts to groundwater (30 cases), 77% had no engineering protection, while of sites with complete data set cases showing no impacts to groundwater (17 cases), 65% had engineering protection. Of facilities located within 5 ft of the CZS, in a sensitive hydrogeologic setting, and employing no engineering protection, 95% (18 total sites) had an indication of impacts to groundwater.

3.6.3 Summary

The information gathered and analyzed in the leachate study indicated that the quality of leachate at C&D landfills in Ohio can be comparable to that of MSW landfill leachate, and for some parameters the measured concentration may be greater. The hydrogeologic study concluded that hydrogeologic setting, siting, and engineering controls all play a meaningful role when evaluating the potential for a C&D landfill to impact groundwater. The OEPA further concluded that the results support the rules that are in place requiring liners and leachate collection systems at C&D debris landfills (OEPA 2011a).

3.7 Virginia – Compliance and Enforcement at C&D Debris Landfills and Processing Facilities

3.7.1 VDEQ Compliance and Enforcement Database

An electronic database of compliance and enforcement activities at C&D debris landfills and processing facilities was provided by Virginia Department of Environmental Quality (VDEQ). The database included information from active C&D landfills from 2000 to 2012 (16 sites), closed or inactive C&D landfills from 2001 to 2006 (3 sites), and C&D processing facilities from 2001 to 2012 (18 sites). The database included an inventory of non-compliance issues, the category or type of non-compliance, and a brief comment section that generally included a short narrative to accompany instances of non-compliance.

The database presented all identified issues of non-compliance as "violations," though some of the comments recognized the issue as an "alleged violation" (e.g., odor complaints related to H_2S that were not necessarily observed by VDEQ inspectors). The number of non-compliance issues coded as "violations" represented more than 80% of all non-compliance issues listed in the database. In some cases, more than one violation was noted in the database related to one activity or event (e.g., a case where acceptance of unauthorized waste was categorized as such and listed under a more general heading of "permit non-compliance"). Efforts were made in this analysis to place a violation in the category that appeared to best fit the violation based on the VDEQ's reference comments.

The most frequent violations cited at active C&D landfills involved compaction and cover and permit compliance. Compaction and cover violations were based on physical observation of a lack of appropriate cover on waste. Multiple instances noted a "fire break" violation – of the 10 reported fire break violations, one instance involved the observance of a fire while the majority (five of the remaining nine instances) involved non-compliance based on related issues such as not maintaining appropriate buffers around disposal piles and maintaining a debris pile greater than 20 ft high without compaction. Permit compliance-related violations included exceeding permitted landfill elevations, accepting waste prior to or after normal operating hours, and placing waste outside the permitted disposal area, among others.

At the closed C&D landfills, closure maintenance-related violations were most commonly observed and included a variety of specific violations (e.g., implementation, inspection, post-closure). Compaction and cover violations were based mainly on lack of a final acceptable cover system. Additionally, violations related to groundwater monitoring were common, but mostly involved a lack of monitoring, reporting, and access to monitoring wells. In a similar fashion, several sites had violations related to "decomposition gas," which corresponded to a lack of monitoring rather than exceedance of a measured parameter.

Common violations identified at C&D processing facilities related to insufficiencies in written operating plans and financial responsibility or assurance. Dust and litter were observed during multiple inspections at facilities as well.

Table 3-5 provides summary statistics of the database and categorizes violations by type. ***Table 3-5*** includes violations of a permitting and reporting nature of a limited number of selected categories; for example, in the leachate category a failure to submit records of leachate removal would constitute a leachate violation. Unauthorized waste acceptance violations of this nature at active C&D landfills include, for example, failing to have a plan that adequately describes procedures for removal and disposal of unauthorized waste, failure to provide training records on unauthorized waste management for new employees, and failure to provide written records regarding a rejected waste load which contained excessive MSW.

Table 3-6 involves counts of facilities where violations referred directly to observations by inspectors. For example, in the leachate category, actual leachate outbreaks from side slopes were observed. Regarding active facilities, compaction and cover violations were observed at seven active sites (ranging from 1 to 6 violations per site), unauthorized waste acceptance occurred primarily at one site (13 of the 20 total violations) and the majority of odor, dust, and nuisance-related violations centered around one site (18 of 25 violations).

Decomposition gas-related violations involved excessive CH_4 levels detected during monitoring. For example, one gas monitoring probe indicated a reading of 12% CH_4 at one site, and another site indicated a reading of 7.1% CH_4, which exceed the VDEQ compliance level of 5% CH_4 (i.e., 100% of the LEL of CH_4 in air). Compaction and cover violations often related to the observance of exposed waste with insufficient cover, oversized working face, and insufficiently covered areas which appeared to have reached final elevation, necessitating intermediate cover and grading to promote surface water run-off.

Table 3-5. Summary of VDEQ Compliance and Enforcement Database for Active and Closed C&DD Landfills, and C&DD Processing Facilities: Classifications of Administrative Violations

Facility Type/ Violation Issue	Compaction/ Cover	Unauthorized Waste	Leachate	Decompo-sition Gas	Designed to Reduce Dust, odor, vector	Other Hazard/ Nuisance[a]
Active LF	0	24	5	4	1	3
Closed LF	2	2	0	12	0	0
MRF/C&D Processing	N/A	5	2	0	6	0

[a] Facility controlling nuisances with methods not previously approved by VDEQ

Table 3-6. Summary of VDEQ Compliance and Enforcement Database for Active and Closed C&DD Landfills, and C&DD Processing Facilities: Issues Observed Upon Inspection

Facility Type/ Violation Issue	Compaction/ Cover	Unauthorized Waste	Fire Prevention	Observed Fire	Leachate	Decompo-sition Gas	Odor[a]
Active LF	67	20	9	1	7	7	8
Closed LF	2	0	0	0	0	0	0
MRF/C&D Processing	N/A	1	0	0	0	0	0

[a] A facility may have been issued a violation based on citizen complaints and observations not necessarily observed by VDEQ inspectors.

Additional categories that made up a substantial portion of observed violations included groundwater, financial assurance and responsibility, operator training, and site closure issues as detailed in ***Table 3-7***. Groundwater violations observed at active facilities included failures to assess corrective measures or submit a proposal for presumptive remedies for statistically significant findings of regulated constituents during groundwater monitoring, regulatory authorities being unable to assess the conditions of monitoring wells due to lack of access roads and steep terrain, and failure to submit annual groundwater reports on time. An instance of a statistically significant finding of a constituent above background does not necessarily indicate a violation.

Table 3-7. Frequency of Additional Violation Categories Identified in the VDEQ Compliance and Enforcement Database for Active and Closed C&DD Landfills and C&DD Processing Facilities

Facility Type/ Violation Issue	Permit Compliance	Financial Responsibility/ Assurance	Facility Closure	Record-keeping/ Reporting/ Written Plans or Manuals	Facility Design/ Construction	Operator/ Employee Training	Ground-water
Active LF	60	35	24	34	74	13	9
Closed LF	0	5	24	9	0	2	17
MRF/C&D Processing	5	20	1	38	21	11	0

3.7.2 Summary

Data on active C&D landfill violations revealed a total of 424 violations at 18 facilities over an approximate 5 year period. Closed C&D landfills were reported as having 72 violations over three facilities. C&D processing facilities had 123 reported violations at 18 facilities. The results underscore the challenges related to operating C&D facilities and the important role that compliance inspections have on site operations. The results also show isolated instances where elevated levels of decomposition gas was measured near C&D landfills, which was identified as a result of VDES's requirement to monitor such gases at C&D landfills. The compliance and enforcement information analyzed also provides an indication of issues that are most commonly encountered at different facility types in Virginia, some of which relate to the broad mechanisms of damage discussed in Section 2, notably impacts that can occur related to improper compaction and insufficient cover soil use.

3.8 Wisconsin – Groundwater and Leachate Quality at C&D Landfills

Two sources of data were examined for the state of Wisconsin: one consisted of a study conducted by staff at the Wisconsin Department of Natural Resources (WDNR) related to groundwater quality at small C&D landfills in Wisconsin, and the other consisted of a review of leachate quality monitoring data from intermediate and large C&D landfills obtained through the WDNR's Groundwater Environmental Monitoring System (GEMS). The groundwater quality study (conducted in 2007) included a very limited amount of data and mostly presented broad summary observations and statistics. The leachate monitoring data were downloaded, organized by site, and summarized to examine temporal trends at one site and overall summary statistics for all sites where data were available.

3.8.1 Groundwater Data Evaluation

The state of Wisconsin regulates and classifies C&D landfills based on the accepted waste volume. Small C&D landfills are those with a capacity <50,000 yd^3. Small, unlined sites are the most common type of C&D landfill in the state. Currently there are four intermediate (50,000 to 250,000 yd^3) size facilities and one large (>250,000 yd^3) facility. In 2007, the WDNR conducted an assessment of groundwater monitoring data collected at 52 small C&D landfills in the state. The age of the landfills examined varied, with the oldest landfills contributing approximately 15 to 20 years of monitoring data. The study was conducted because previous groundwater data evaluation efforts by the WDNR in 1991 and 1994 indicated that there was insufficient history of monitoring data at the small C&D landfills to observe temporal trends in groundwater quality. However, the previous studies conducted in 1991 and 1994 showed that large C&D landfills had impacted groundwater (Kalvelage 2007).

The Kalvelage (2007) study noted that 60% of small C&D landfills in the state exhibited impacts to groundwater (note that the term "impacts" was not clearly defined). Older landfills tended to make up a disproportionate amount of the adverse effect cases; 71% of unlined C&D sites older than 10 years showed adverse impacts to groundwater. Impacts were observed in 50% of cases of C&D landfills older than 5 years. Sulfate was noted as a chemical that had elevated concentrations in the 1991 and 1994 studies, while manganese was noted as an additional chemical of concern based on the 1994 study.

The WDNR evaluated the impact of soil type, distance to the water table, and landfill age on the observed groundwater impacts at the small C&D landfills. Twenty-six out of 39 sites situated in sandy soil showed impacts to groundwater, while four of eight sites located in clay or silty clay soils showed impacts. Approximately 83% (10 of 12) landfills with a separation distance of at least 50 ft to the groundwater table showed elevated concentrations of groundwater constituents. Also, 25%, 50%, and 71% of sites less than 5 years old, 5 to 10 years old, and greater than 10 years old were found to have impacted groundwater, respectively.

3.8.2 Leachate Data from C&D Landfills Evaluation

The publicly available WDNR GEMS database was used to gather data related to leachate quality from C&D landfills. Data were available for five sites (intermediate and large sites that require leachate collection) spanning a total of 45 unique sampling events between 2006 and 2012. The database included 3,063 measurements of 114 water quality parameters including field parameters (e.g., pH and specific conductivity), inorganic, and organic compounds. Sixty-five parameters were detected in at least one sample (11 parameters were detected below the limit of quantitation). The average number of years of data available for each site was approximately 4 years, with a range of 1 year to 6 years. The database included information on the location(s) at which leachate samples were collected – four sites listed leachate collection system and one site listed a leachate head well as the point of collection.

Approximately 13.5% of samples (5 instances) had a field pH outside the range of 6.5-8.5 (all were less than 6.5); the minimum pH observed was 5.71. Of the 23 inorganic constituents detected, nine do not have current MCLs, SMCLs, US EPA aquatic life guidelines, or Wisconsin public health or public welfare groundwater standards. Eight of 14 inorganic parameters with a regulatory standard exhibited an exceedance of the standard at least once. Manganese (42 measurements), iron (40 measurements), and sulfate (25 measurements) were the constituents that most frequently exceeded the corresponding standard. ***Figure 3-4*** presents an example series of time plots for one of the facilities that had 6 years of leachate data. The results in ***Figure 3-4*** show that sulfate, iron, and manganese were frequently measured at concentrations above applicable corresponding standards. ***Figures 3-5*** and ***3-6*** present plots of the aggregated data for the detected inorganic parameters in leachate from intermediate and large C&D landfills in Wisconsin. The aggregated data show that manganese, iron, arsenic, and sulfate exhibited a median concentration greater than the applicable groundwater standard. These data, along with the data shown in ***Figure 3-4***, appear to be consistent with the conclusion of the groundwater evaluation conducted for small C&D landfills in Wisconsin, which identified manganese and sulfate as two primary constituents of concern.

The average median to standard ratio (from the results shown in ***Figure 3-5*** and ***3-6***) was 14.3 in instances where a parameter showed at least one exceedance of a corresponding groundwater standard. Approximately 54% of inorganic parameter measurements with regulatory standards were detected at a concentration greater than the Wisconsin standard. Five inorganic parameters (chromium, copper, molybdenum, carbon disulfide, and mercury) were detected infrequently and never observed at concentrations greater than the respective standard.

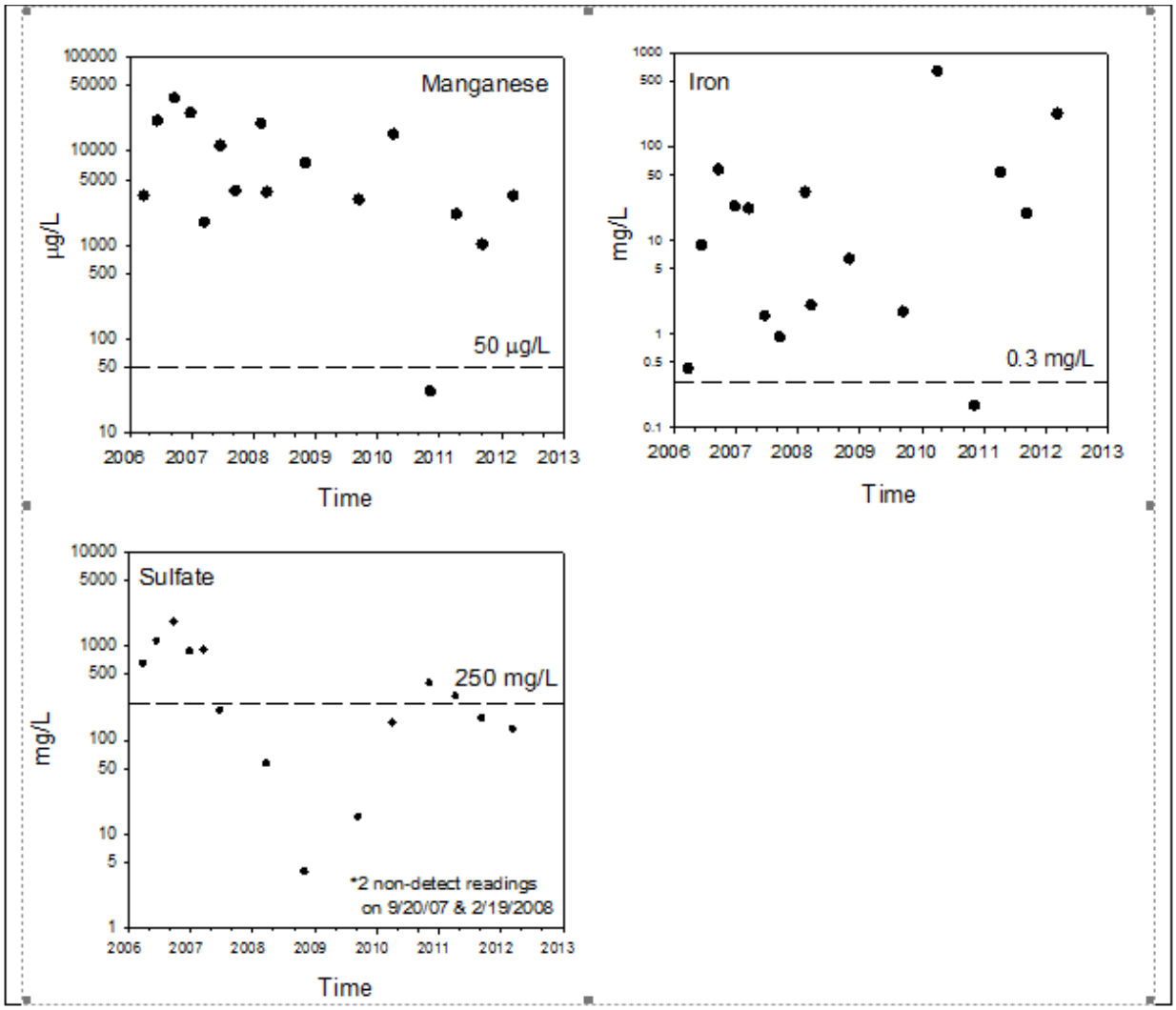

Figure 3-4. Temporal Variation of the Most Commonly Observed Leachate Parameters at One C&D Landfill Site in Wisconsin Compared to Corresponding Constituent Target Levels

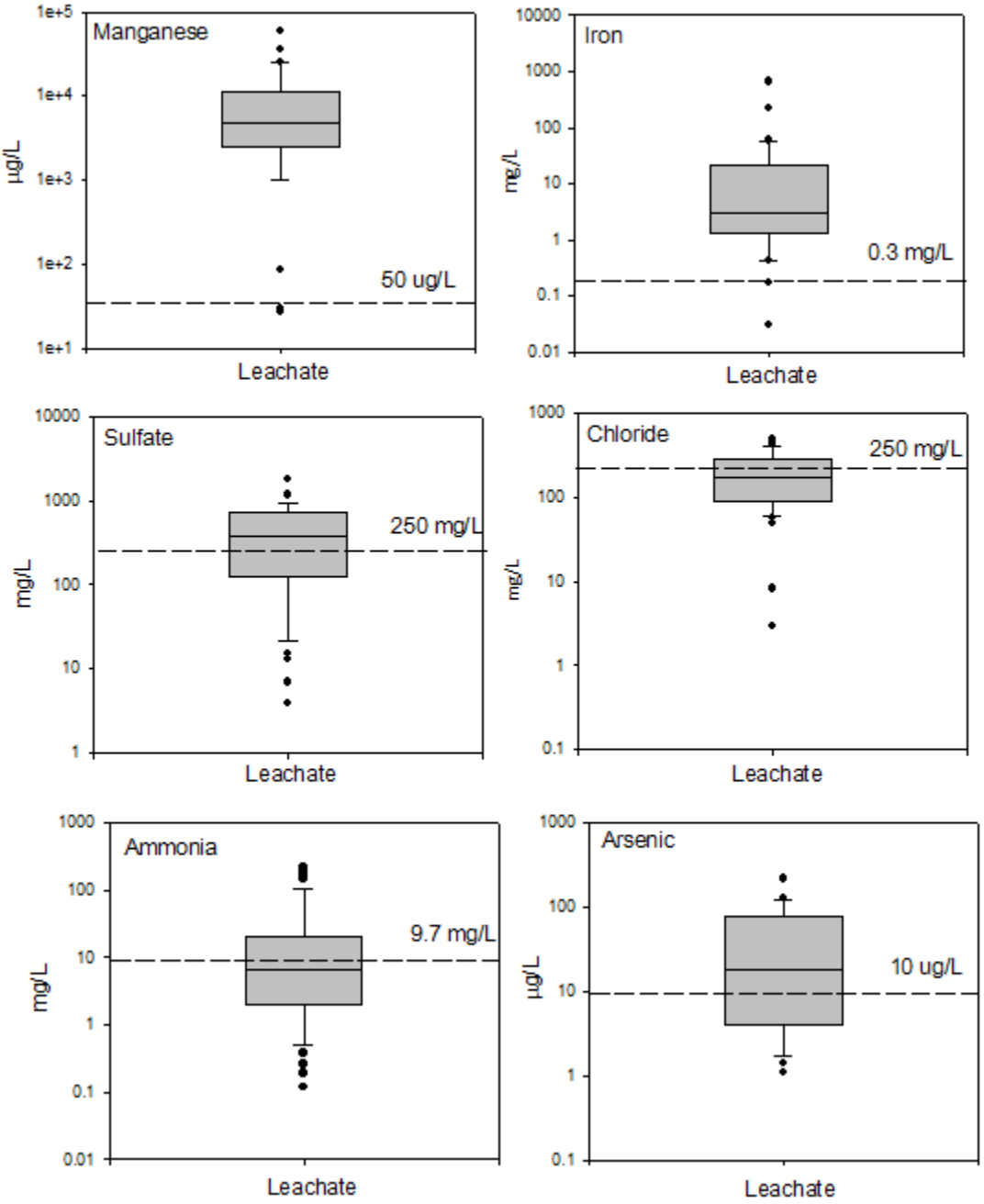

Figure 3-5. Inorganic Parameters Measured in Leachate from Wisconsin C&D Landfills

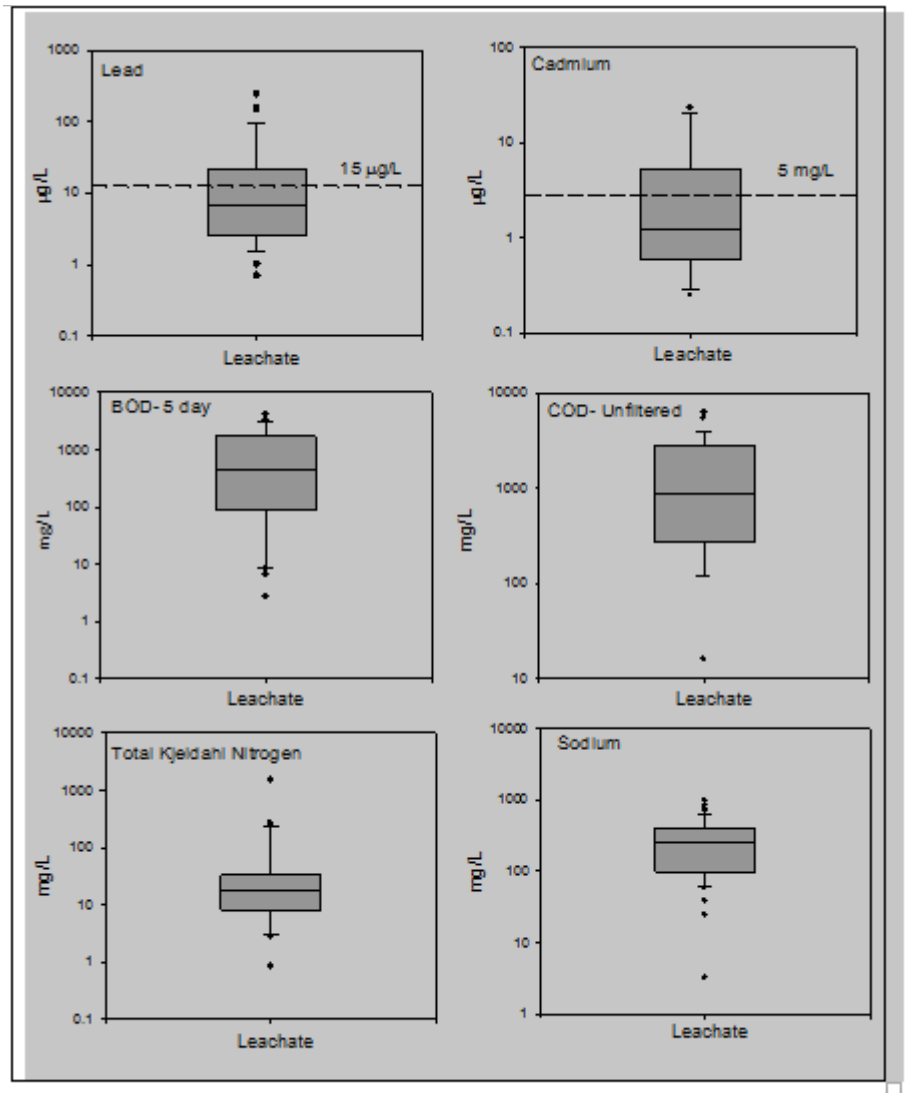

Figure 3-6. Summary of Inorganic Parameters Measured in Leachate from Wisconsin C&D Landfills

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Figure 3-6. Summary of Inorganic Parameters Measured in Leachate from Wisconsin C&D Landfills

Figure 3-7 presents a summary of detected VOCs in leachate. Approximately 87 % of the organic compound measurements were below the laboratory detection limit (1,983 below detection limit). Of the detected organic compounds, toluene (32 measurements), fluorotrichloromethane (30 measurements), naphthalene (20 measurements), and tetrahydrofuran (17 measurements) were the constituents most commonly detected. Only the median concentration of tetrahydrofuran however, exceeded the regulatory standard (approximately 4 times greater).

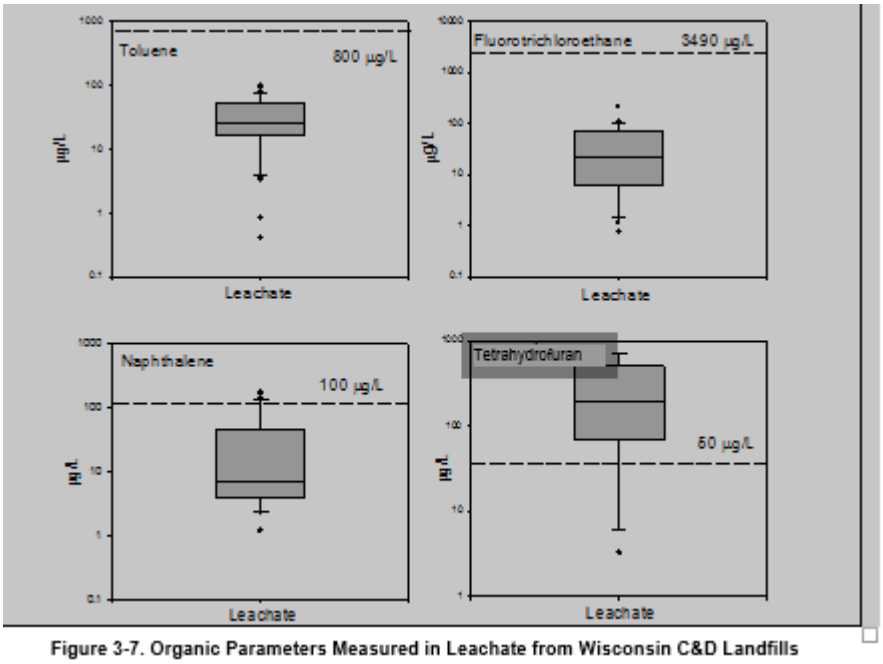

Figure 3-7. Organic Parameters Measured in Leachate from Wisconsin C&D Landfills

Figure 3-7. Organic Parameters Measured in Leachate from Wisconsin C&D Landfills

3.8.3 Summary

The groundwater monitoring data collected at small C&D sites in Wisconsin suggest that impacts have occurred at several sites. The observed impacts have been seen in cases where the natural soils include clays and silty clays and where the travel distance to the groundwater table is fairly large. Fairly limited information was available regarding the magnitude of impacts to groundwater as well as the specific constituents of concern, though sulfate and manganese were two parameters mentioned. Several years of monitoring data of collected leachate at five C&D sites suggested leachate quality showed the median concentrations of iron, manganese, sulfate, arsenic, and tetrahydrofuran exceeded the corresponding regulatory limit in instances of detection for the entire data set. The detections of sulfate and manganese are consistent with the results of the small C&D landfill groundwater evaluation.

4. Detailed Damage Case Evaluation

4.1 Overview and Methodology

The previous two sections (Sections 2 and 3) presented information regarding damage at C&D facilities in a progressively more detailed manner. Section 2 presented an inventory of damage sites based largely on feedback and information gathered from state solid waste regulatory personnel, and Section 3 presented an analysis of large-scale summary statistics on actual or potential environmental impacts or damages based on reports prepared by state regulatory agencies or available environmental monitoring data. In this section, damage is evaluated in a more acute manner by evaluating three specific instances of damage at the facility level. The examination of specific facilities allows for a more complete picture of environmental damage and provide context regarding the causes of damage (e.g., whether damage was the result of permit non-compliance).

The three sites were selected following discussions with and feedback from the US EPA regions and the US EPA Office of Resource Conservation and Recovery on routine conference calls during the project. Criteria for selection included (1) whether a given site had substantially available information regarding operations, monitoring, and permits; (2) geographic distribution; and (3) prevailing or primary damage type. The selected sites and basic information regarding their location and identifying information is provided in ***Table 4-1***. Available information about each site was gathered and evaluated with respect to several potential "damage" indicators. The information evaluated for each site included the following:

- overview of the site/history,
- operations information and permit-related information,
- documentation of environmental damage, and
- applicable regulatory and/or remedial actions.

In contrast to the US EPA (1995b) damage case evaluation (which primarily evaluated groundwater and surface water impacts at C&D debris landfills), the damage assessment in this project was conducted using a multimedia approach, which included evaluating impacts to water and air, as well as examining more local impacts such as fires. The sites selected for analysis meet the criteria that were used to define a facility as a "damage" site as described in Section 2.1.

Table 4-1. Summary of Detailed Damage Case Sites Selected and Corresponding Identifying Information

Site Name	Primary Site Type	Site Location	Identifying Information
Saufley Landfill	C&D Landfill	Pensacola, Escambia County, Florida	Primary damages include H_2S emissions, groundwater impacts, and fires
Archie Crippen Excavation Site	C&D Recycling Facility	Fresno, Fresno County, California	Primary damage includes fires
Warren Landfill and Recycling Facility	C&D Landfill	Warren, Trumbull County, Ohio	Primary damages include H_2S emissions and groundwater impacts

The information presented in this section was gathered from a variety of sources, including

- scientific literature,
- regulatory guidance documents,

- health consultations,
- site permits and regulatory submittals,
- regulatory inspections, and
- auditor reports.

4.2 Damage Case 1: Saufley Landfill (Escambia County, Florida)

The Saufley C&D Landfill (site) accepted debris between 1990 and 2006. The primary issues associated with the site include emission of H_2S from disposed drywall in the landfill and particulates from fires that occurred at the site. Approximately 2,000 residents lived within a 1-mile radius of the site, and several dozen reported inhalation-related health effects to the local health department. There has also been observation of groundwater impacts based on several years of monitoring data as well as historical off-site stormwater and sediment transport. An order to close the site was issued by FDEP in 2008, but the site owner did not complete the necessary actions and abandoned the site. Escambia County took responsibility to close the site, and closure activities at the site are ongoing as of 2012.

4.2.1 Site Description

The site is an approximately 23-acre unlined C&D debris disposal facility located in Pensacola, Florida. It is bordered on three sides by varying-density residential areas, and is bounded on the west by Saufley Field Naval Air Base. The grades surrounding the landfill are at approximately 85 ft National Geodetic Vertical Datum (NGVD) while the highest site elevation (top of landfill) is approximately 130 ft NGVD. Previous documentation (Condor Earth Technologies 1998, Gallet and Associates 2003) indicates the site was previously used as a sand borrow pit which was about 30 ft deep, suggesting waste at the site may be up to 75 ft thick. ***Figure 4-1*** presents the layout of the site showing the approximate location of the groundwater monitoring network.

The soil underlying the site consists of the Florida Gravel-and-Sand Aquifer of the western panhandle, which is comprised of three layers (or zones) including a surficial zone (Wilkins et al. 1985, Roaza et al. 1993, Condor Earth Technologies 1998). A total of nine groundwater monitoring wells were installed within the surficial zone; groundwater sampling has occurred semiannually since 1999.

The site was operated as a sand mine for some time prior to 1968 until about 1981 (Gallet and Associates 2003). The site first started accepting C&D waste in 1990. Records from 1999 to 2003 show an annual waste acceptance rate of approximately 40,000 tons per year, but Hurricane Ivan in 2004 and other tropical storms resulted in a significant increase in waste acceptance at 400,000 tons in 2004 and 250,000 tons in 2005. Approximately 120,000 tons of waste were accepted in 2006 prior to the site closing on August 8, 2006. On March 4, 2008, due to failure to close the site in accordance with various court orders and deadline extensions, the Florida Department of Environmental Protection (FDEP) issued a Final Order of Abandonment.

Escambia County assumed responsibility for the site August 24, 2009, through a Prospective Purchaser Agreement to implement closure and post-closure construction and monitoring activities after abandonment by the previous owner. Part of these closure activities will include the relocation of approximately 200,000 yd^3 of waste to reduce the height of the fill, and site closure according to Florida Administrative Code (FAC) 62-701.730(9)(b), which includes bringing the side slopes to maximum 3:1 (horizontal to vertical) grades, installing an artificial turf-covered geomembrane, and completing a stormwater management system to prevent runoff and provide erosion control. Final closure activities were initiated mid-2012.

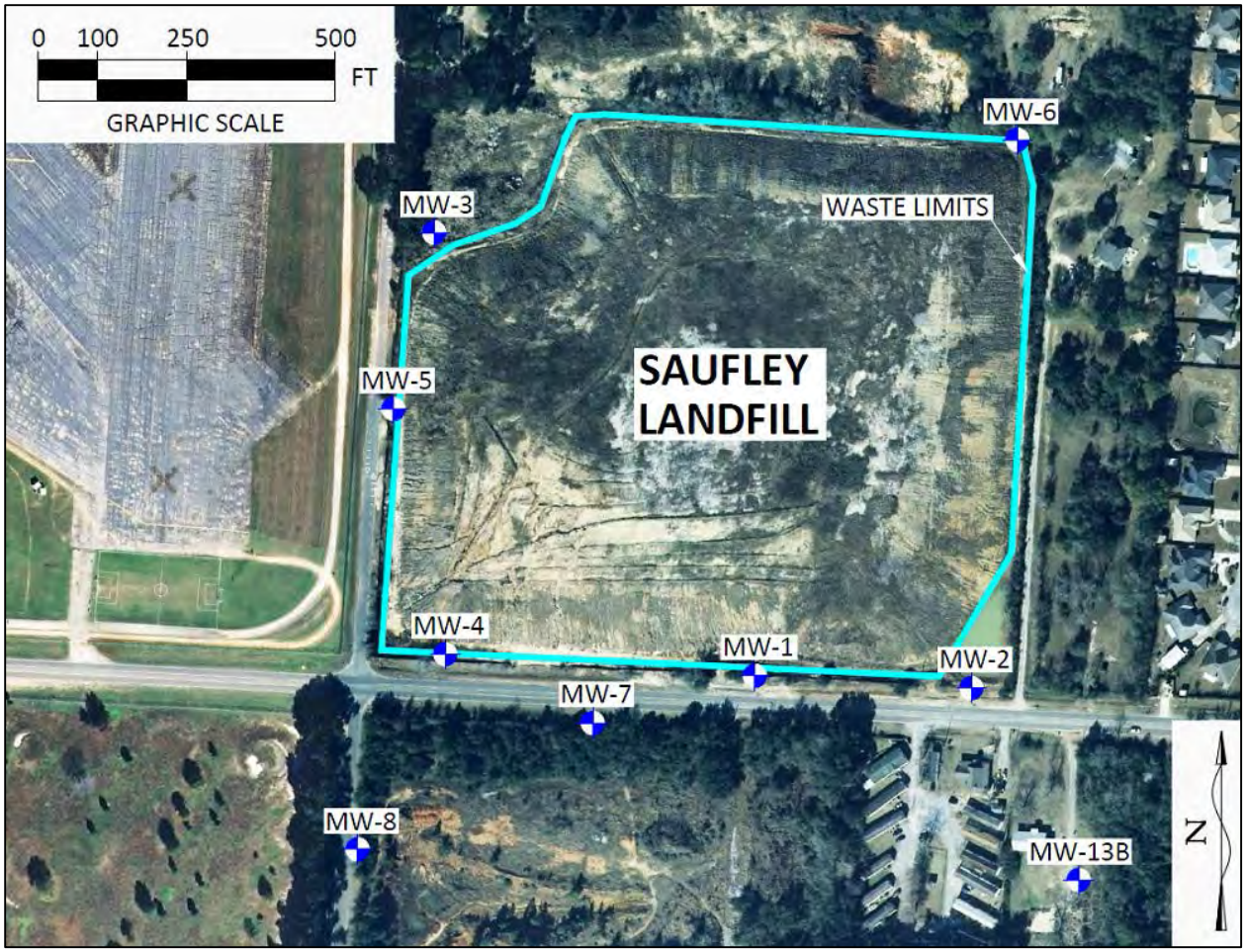

Figure 4-1. Site Layout Showing Approximate Location of Groundwater Monitoring Wells (Aerial Imagery from FDEP Bureau of Survey and Mapping, December 2009)

4.2.2 Regulatory and Compliance History

Florida C&D debris landfills are regulated according to 62-701.730, FAC, which includes semiannual groundwater monitoring, waste compaction and grading, final cover installation, waste screening, stormwater management, and odor control. As discussed in Chapter 2, Florida solid waste regulations do not require the installation of bottom liners and leachate collection systems unless the FDEP demonstrates that site-specific conditions require these systems. Florida solid waste rules for C&D landfills do not specify a minimum operational cover soil requirement, but the site had a specific condition in its 2002 operations permit that required application of soil cover on a weekly basis.

The following sections provide a discussion of major milestones and relevant compliance-related issues at the site based on a review of site records, permits, inspection documents, and related information.

1988–1995

C&D debris placement into the excavated sand pit began in approximately August 1990 when the Florida Department of Environmental Regulation issued a General Permit to Operate a Construction and Demolition Debris Disposal Facility, which followed an Escambia County October 1988 issuance of a Permit to Operate a Solid Waste Management Activity. From 1990 to 1995, the most common non-compliance citations recorded during regulatory inspections were the acceptance, disposal, and/or storage

of unauthorized, non-C&D debris waste (e.g., white goods, clothing, residential garbage, and vegetative debris), the deposition of "unclean" (non-inert) C&D waste in standing water at the site, and inadequate site access control. Based on a review of inspection report narratives, it appears that standing water located on the bottom of the site's pit floor occasionally represented the groundwater table.

1995–1999

Non-compliance issues involving the acceptance and disposal of unauthorized waste, as well as non-"clean" waste deposition in standing water continued, though additional efforts to address these instances of non-compliance were noted on inspection report logs. The first discovered instance of an off-site odor complaint was documented in July 1998, but after the application of cover soil and lime, FDEP inspectors recorded that odors were no longer detectable in August 1998.

2000–2004

Instances of operating with steep operating slopes were first indicated during this time period. In February 2000, FDEP inspectors noted that side slopes were steeper than 3:1 (note that while current FDEP rules require operating slopes at C&D landfills to be less than 3:1, the rules at the time only required side slopes at 3:1 at the time of closure).

A landfill fire was documented in an FDEP inspection on 18 June 2000, but was brought "under control" by June 20, 2000, and "no evidence of smoke or fire" was found in follow-up inspections on June 27 and 29, 2000. An FDEP inspection noted that "a lot" of water was used in initial efforts to extinguish the fire.

Prohibited waste acceptance continued to be the primary non-compliance issue noted in FDEP inspection reports until May 2002. FDEP inspection logs mention that on November 17, 2002, another subsurface fire started that did not appear to be extinguished until January 6, 2003. Following this landfill fire event, frequent odor complaints from nearby residences occurred through April 2003. In October 2003, FDEP recorded two additional complaints regarding odor, noise, and dust emissions from the site.

Numerous instances of failure to apply weekly cover and control the size of the working face were documented starting in 2003, which is likely attributable to the large increase in waste acceptance resulting from Hurricane Ivan and tropical storms during this time.

2005–Present

A Notice of Violation (NOV) was issued by FDEP in February 2005 requiring a small working face to minimize waste and stormwater interaction, apply weekly cover, and implement corrective actions concerning groundwater contaminants that were discovered beyond the property line (constituents included iron, aluminum, manganese, and TDS). The NOV was followed by a Final Order which required the site to conduct a contamination assessment. The site owner/operator at the time agreed to submit a Site Assessment Report following a consent order issued in May 2005.

In June 2005, the site had exceeded the permitted design elevation of 120 ft NGVD and side slopes were steeper than 3:1. On 21 November 2005, a fire was reported by a site operator. On 5 January 2006, the Escambia County Health Department issued a Health Advisory as a result of smoke emissions from the fire. On January 23, 2006, a consent order was signed requiring fire extinguishment prior to 16 February 2006 and grading of side slopes to less than or equal to 3:1. From January 23 to 25, 2006, the US EPA performed ambient air tests to measure concentrations of multiple air pollutants – a health consultation that used these sampling results indicated H_2S concentrations were not low enough to ensure the protection of human health (US EPA 2006a). The November 2005 fire was documented as extinguished on February 20, 2006.

A court order was issued that required the site to lower the elevation of the waste to below the permitted 120 ft NGVD, close the landfill, and provide topographic surveys to demonstrate that the required waste elevations had been achieved. A fire broke out on August 28, 2006, during waste leveling and onsite relocation activities and reportedly smoldered for about a month.

The Florida Department of Health (FDOH), in cooperation with the Agency for Toxic Substances and Disease Registry (ATSDR), executed an ambient air monitoring program to measure H_2S and particulate matter (PM) concentrations using a combination of stationary and personal badge monitoring devices in October 2006 (more details on the results of this study are presented in Section 4.2.3).

Strong odors were reported by FDEP inspectors following the fire that occurred from November 2006 through March 2007. From April 2007 to February 2008, the site operator attempted to close the site by attempting to lower the waste elevation to 120 ft NGVD, installing a final cover, and constructing a stormwater management system. During this time period, there were several reports and inspections that documented stormwater runoff and cover soil washing onto adjacent properties and roads. Odor complaints continued throughout this period.

In February 2008, the FDEP issued a Final Closure Order requiring the facility to be closed within 21 days. When the operator failed to initiate closure activities or request a time extension within the 21-day deadline, the FDEP issued a Final Order of Abandonment. Subsequent to the Final Order of Abandonment, Escambia County acquired the property and took responsibility to address the issues at the site.

Figure 4-2 presents a timeline of key events at the site, including non-compliance events, major storm events, and related site activities.

Figure 4-2. Timeline of Non-Compliance and Hurricane Events for the Saufley Landfill (Bars Represent Recurring Non-Compliance Issues as Noted in FDEP Inspection Logs)

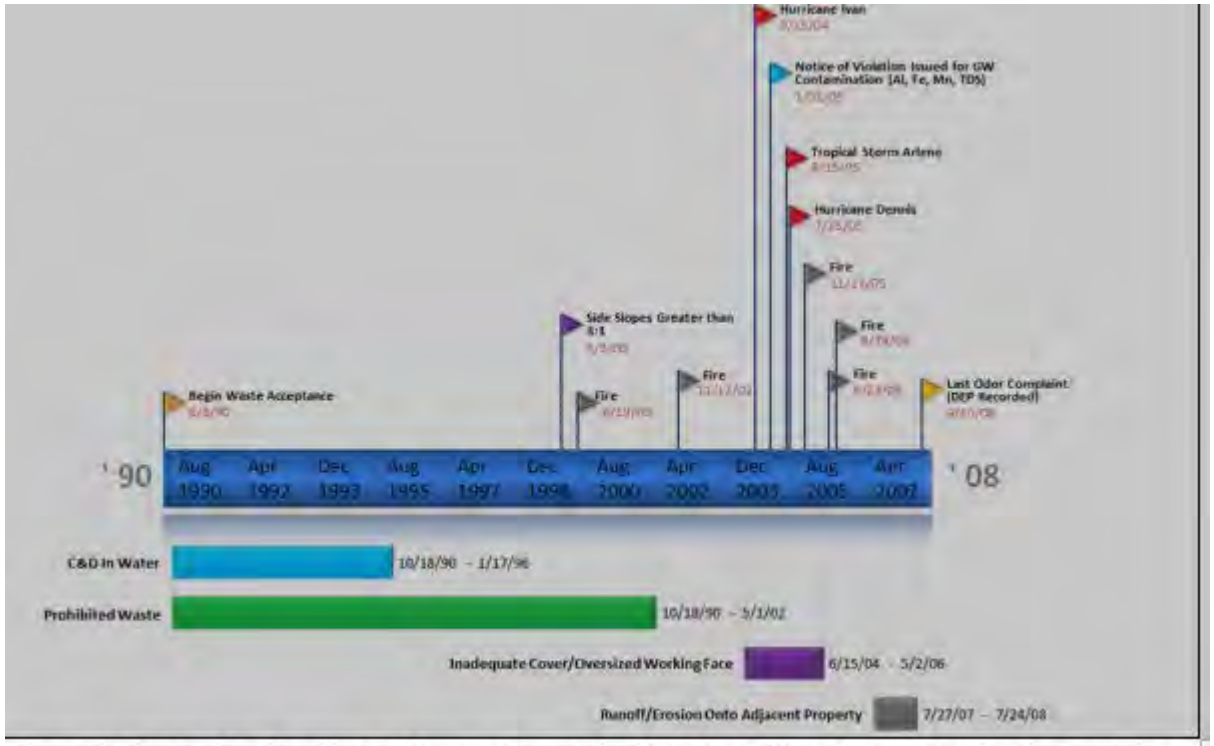

Figure 4-2. Timeline of Non-Compliance and Hurricane Events for the Saufley Landfill (Bars Represent Recurring Non-Compliance Issues as Noted in FDEP Inspection Logs)

4.2.3 Discussion of Damage

This section presents a discussion of damage based on review of information from the site, with particular focus on groundwater impacts as demonstrated by routine monitoring data, odors caused by H_2S emissions, and issues associated with landfill fires.

Groundwater Impacts

Groundwater has historically flowed from north to south across the site, though several contour plots included in semiannual groundwater monitoring reports (e.g., fall 2004, spring 2006) have suggested occasional flow towards the southeast or southwest.

Table 4-2 presents a summary of groundwater monitoring data for the parameters that exceeded the GCTL at least once between spring 1999 and spring 2012. During the sampling period, a total of 17 constituents were measured at concentrations that exceeded the respective GCTL; however, five of the 17 constituents measured above the GCTL were observed only at off-site wells, thus ***Table 4-2*** only presents the remaining 12 parameters that exhibited an exceedance at on-site compliance wells. There are two background wells for most of the historical sampling period, MW-3 and MW-6. Well MW-3 is located in the northwest portion of the site and has been identified as potentially impacted by historical waste disposal activities at the parcel to the north.

Table 4-2. Summary of Parameters Exceeding GCTLs at Groundwater Monitoring Wells at the Saufley Landfill

Monitored Parameter	Units	GCTL[1]	Number of Measurements (Exceedances of GCTLs)		
			Background	Compliance	Off-site
Ammonia - N	mg/L	2.8	34(9)	58 (52)	4(2)
Sulfate	mg/L	250 (S)	37(1)	62(8)	20
Sodium	mg/L	160	34	58(4)	4
Total Dissolved Solids	mg/L	500 (S)	37(13)	62(45)	20(9)
Aluminum	mg/L	0.2 (S)	36(6)	61(12)	11(5)
Arsenic	µg/L	10	36(7)	61(10)	8(1)
Barium	µg/L	2,000	6	10(1)	0
Cadmium	µg/L	5	34	58(1)	4
Iron	mg/L	0.3 (S)	37(17)	62(62)	20(19)
Lead	µg/L	15	33(1)	58(1)	4
Manganese	mg/L	0.05 (S)	8(4)	12(12)	7(6)
Phenols, Total	µg/L	10	25(2)	39(3)	-

Note: 1. (S) Denotes a secondary drinking water standard.

A comparison of data presented in ***Table 4-2*** indicates that impacts from landfilling on groundwater quality occurred. Ammonia, iron, and manganese exceeded the GCTL in 90%, 100%, and 100%, respectively, of all measurements in downgradient wells.

A variety of factors not necessarily related to compliance likely contributed to the groundwater impacts observed at the site. First, the landfill was not constructed with a bottom liner or leachate collection system, thus no substantial barrier between the bottom of the waste and the surficial aquifer was present. Second, the site was originally built on a sand and gravel pit in a hydrogeologic setting that would not be expected to slow down percolation of chemicals that may leach from the waste mass. These two factors

are consistent with the factors identified in Section 3 as having a substantial impact on groundwater quality observed at C&D debris landfills.

The review of historical operating and inspection records for the site also indicates that several non-compliance issues may have contributed to groundwater impacts at the site, including:

- Unauthorized waste acceptance. FDEP inspection logs frequently indicated prohibited waste acceptance between 1990 and 2002. Examples of prohibited wastes accepted included white goods (i.e., appliances) and residential garbage.
- Placement of waste within standing water. Non-"clean" debris was frequently cited in historical inspections between 1990 and 1996 as being placed in standing water.
- Recurrent fires at the site which necessitated the use of a large amount of water to extinguish the fire. The addition of large volumes of water, coupled with the frequently cited cover soil application deficiencies, likely contributed to a greater amount of liquids percolation through the landfill than would have occurred had recurrent fires not been an issue. The presence of a greater amount of liquid percolating through the waste mass would be expected to generate larger volumes of leachate, thus exposing the underlying aquifer to a greater amount of leached chemicals from the waste mass.

While the factors described above demonstrate factors related to non-compliance that may have contributed to the impacts to groundwater that were observed, it is noted that several of the constituents that were measured in concentrations exceeding the GCTL (e.g., sulfate, iron, manganese, and arsenic) are consistent with those identified in C&D landfill leachate (e.g., in the Ohio study) and in groundwater near C&D debris landfills as detailed in Section 3. Thus, the groundwater impacts observed at the Saufley landfill may have occurred regardless of whether the facility had the non-compliance issues described above.

Odors and Particulate Emissions

Numerous odor complaints as a result of H_2S emissions as well as the presence of fires occurred at the site during its operational life. The first recorded odor complaint was in July 1998, but after the application of dirt and lime to the area, no odor was detected during a follow-up inspection 2 weeks later. The next period of recurrent odors began in late 2002 at the time of an extended fire event. Odors were also reported multiple times between September and October 2003. The most recent and prolonged instance of odor complaints followed a 3-month fire event that began in November 2005. Odor complaints were received intermittently following this fire until September 2008. ***Figure 4-3*** presents an aerial image of the site showing the locations of residents that filed odor complaints recorded by FDEP between 2002 and 2008. Complaints were submitted by residents as far as a half mile away from the site.

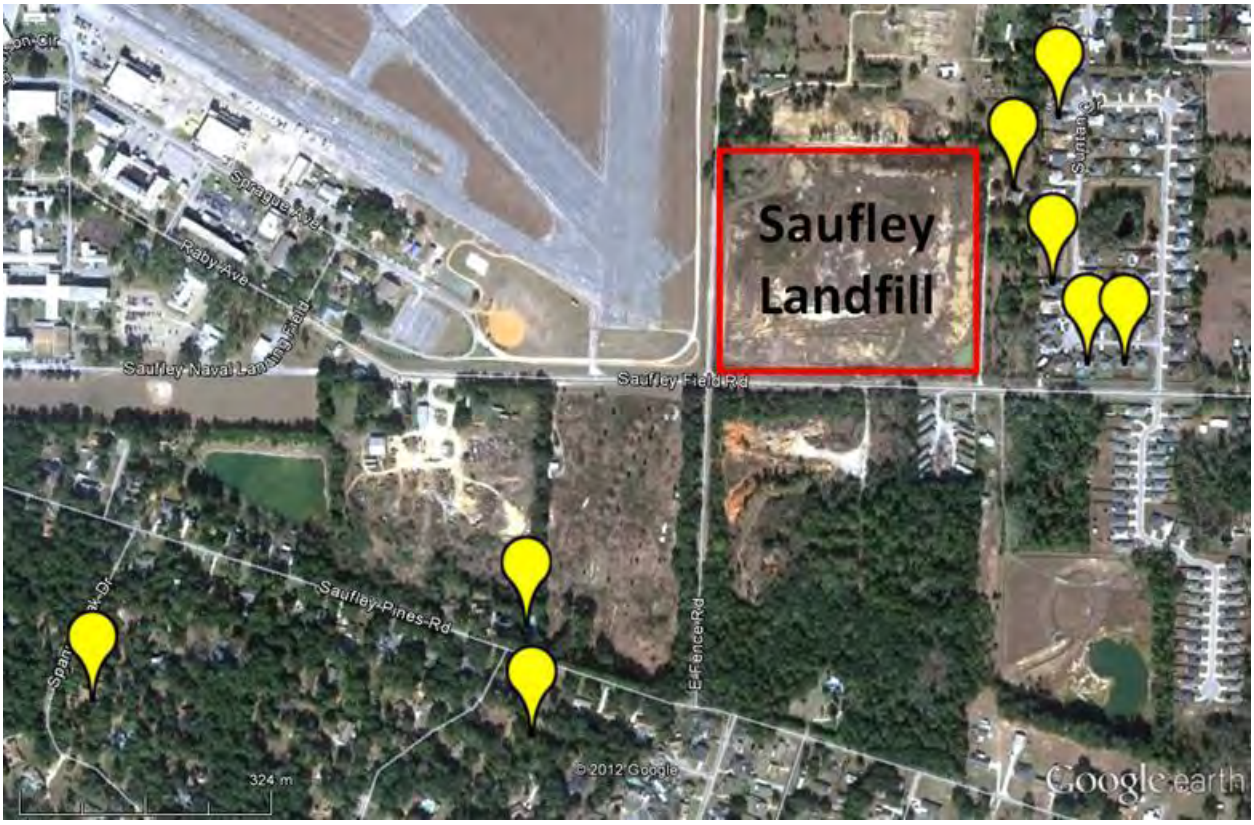

Figure 4-3. Odor Complaints from Residences Near the Site Between 2002 and 2008 Based on FDEP and FDOH Inspection Logs

During a February 2, 2007, complaint-related inspection event, FDEP and FDOH officials met at the site to investigate reports that landfill operators fell ill with nausea and headaches due to H_2S exposure (FDOH 2007). The H_2S meter brought to the site was non-functional and could not accurately measure ambient concentrations; however, 10 minutes following the site visits, it was noted that FDEP inspectors felt nausea and experienced headaches.

Table 4-3 presents a summary of five H_2S monitoring events or periods that occurred between January 2006 and May 2012. The data show varied results based on the type of instrument used, the location of sampling, and time period when monitoring took place. The maximum measured concentrations were observed in early 2007, with concentrations as high as 140 parts per million (ppm) at the landfill surface and 10 ppm at the site perimeter. The World Health Organization (2003) indicates that concentrations of H_2S greater than 100 ppm can cause olfactory paralysis, which is particularly problematic in that levels exceeding the point of olfactory paralysis can inhibit a human's ability to detect even more harmful concentrations (e.g., H_2S concentrations greater than 500 ppm can cause death [World Health Organization 2003]).

Table 4-3. Summary of H_2S and Other Air Quality Parameter Monitoring Events at the Saufley Landfill

Date or Date Range	Sampler and Data Source	Location	H_2S Monitoring Equipment	Max. H_2S Concentration (ppb)	Discussion
23-27 Jan. 2006	US EPA On-Scene Coordinator Readiness Task Force (US EPA 2006a)	Site boundary, surrounding communities	Hand-held meter (MultiRae)	No Detections	Testing occurred after fire event, included measurements of carbon monoxide (CO), sulfur dioxide, volatile organic compounds, PM, and asbestos – results were generally below detection limit, but the study concluded H_2S concentrations were not low enough to ensure protection of human health.
22 Oct. 2006 - 8 Feb. 2007	FDOH (2007)	Surrounding residential areas	Fixed position monitors, personal badges	▪ 224 (fixed monitors) ▪ 123 (personal badges)	ATSDR concluded the site presented a "public health hazard", defined as "sites that have certain physical features or evidence of chronic, site-related chemical exposure that could result in adverse health effects" (ATSDR 2006).
5 Feb. and 21 March 2007	ATL, Inc. (Escambia County Circuit Court (2007a, b))	Inside onsite excavator, outside onsite excavator, landfill surface, landfill perimeter	Hand-held meter	▪ 20,000 (inside excavator) ▪ 120,000 (outside excavator) ▪ 140,000 (landfill surface) ▪ 10,000 (landfill perimeter)	From a review of reference documentation, it appears that the two highest readings listed during this monitoring event were taken from within 1 ft of the landfill surface.
8, 9, 26 Feb. 2007	Escambia County Department of Health	Areas surrounding landfill (Metzler (2007); Pearce (2007); Rivers (2007)	Hand-held meter	120 (east of landfill)	It is unknown the exact locations where sampling took place.

The occurrence of fires and the emission of H_2S were likely caused by a variety of factors, as discussed below.

- Cover Soil Application. The site was required to apply cover soil at least weekly for the bulk of the operating period examined. Using cover soil reduces rainwater infiltration into the waste and

acts as a barrier to trap or remove H_2S (as discussed by Townsend et al. 2004c, Plaza 2007, Xu et al. 2010a, Xu et al. 2010b), and routine use of cover soil can help prevent fires by creating a barrier that limits air infiltration into the waste mass. One of the most frequently cited non-compliance issues at the site was the failure to adequately apply cover soil.

- Large Working Face. The site was required to maintain a small working face to avoid large areas of exposed waste. However, a frequently cited compliance issue related to maintaining a large working face. A large working face allows a larger area to be exposed to rainfall (thus introduction of moisture into the waste, which can contribute to H_2S emissions as described previously). Also, a large working face can allow the waste to be exposed to oxygen, which can be problematic if a surface or subsurface fire is occurring.
- Steep side slopes. The presence of steep side slopes, coupled with a lack of cover soil, creates a condition where prevailing winds can infiltrate side slopes and create a chimney effect, thus potentially exacerbating fire issues. Steep operating side slopes at the site were noted in FDEP inspection logs as far back as 2000. The use of steep operating side slopes, however, was not in violation of FDEP rules or the site's permit.

Inspection and monitoring records related to PM measurement are limited. As ***Table 4-3*** shows, PM testing was conducted in early 2006 at the site, but the results did not indicate high PM levels (the highest reading was 567 $\mu g/m^3$ in a 5-minute time-weighted average [TWA] reading, less than the ATSDR action level of 3,500 $\mu g/m^3$ for black smoke). The US EPA (2006) evaluation indicated that the short duration of sampling suggested the results were not likely representative of the conditions experienced in the atmosphere near the landfill during the previous fire events, some of which had lasted months. A summary of documented observations of fire at the site are summarized in ***Table 4-4***.

Table 4-4. Summary of Landfill Fire Observations Noted in Inspection Reports and Approximate Duration Until Fire Was No Longer Observed at the Saufley Landfill

Approximate Time Fire First Observed	Approximate Duration Until Fire No Longer Observed
June 2000	< 1 Month
November 2002	3 Months
November 2005	3 Months
June 2006	< 1 Month
August 2008	1 Month

Based on the odor and fire issues observed at the site, these problems were caused by a combination of factors, some of which did and some of which did not relate to facility non-compliance. The presence of drywall (which is a common component of C&D debris), the percolation of moisture into the waste, and other conditions typical of C&D landfills would likely have caused the formation and emission of H_2S at the site. However, the recurring cover soil application non-compliance as well as noted events where large amounts of moisture were introduced into the landfill as part of fire-fighting caused conditions conductive to the formation and emission of H_2S to be exacerbated.

As for fires, the exact cause of fires in the waste was not clearly identified in inspection reports (though previous operations plans for the sites suggested the receipt of "hot loads" may have contributed to the fires), so it cannot be said with certainty whether the landfill fires that occurred were a direct result of non-compliance or would have occurred anyway. The routine presence of steep slopes, which were allowable at the site per the facility's permit, coupled with the large amount of waste accepted in the 2004

to 2005 timeframe, which appeared to preclude appropriate compaction of the waste, likely were strong contributing factors to the site's prolonged fire issues.

Site Damage Summary

Table 4-5 depicts a summary of the environmental damages noted at the Saufley Landfill and some potential non-compliance issues that may have contributed to their development. The information in ***Table 4-5***, which is based on the discussion provided previously, indicates that the damage observed at the site resulted from normal operations (i.e., operations that were in compliance with the facility's permit) and from the site failing to comply with some conditions of its permit. The magnitude of impacts observed was likely augmented by the facility's non-compliance. Although the costs related to addressing odors and other damages from the site are not known, Escambia County contracted to close the landfill in accordance with FDEP rules. Closure activities are ongoing, but the estimated cost to close the site, which includes debris removal, stormwater management area construction, and final cover installation, is expected to be $6 million (Page 2011).

Table 4-5. Summary of Site Environmental Damages and Potential Contributing Factors Related to and Not Related to Facility Non-Compliance at the Saufley Landfill

Damage	Contributing Factors Not Related to Facility Non-Compliance	Contributing Factors Related to Facility Non-Compliance
Groundwater Impacts	▪ Lack of bottom liner and leachate collection system ▪ Hydrogeology of the site (permeable surficial aquifer) ▪ Chemical nature of C&D waste (observed at other sites in other states as detailed in Chapter 3)	▪ Prohibited waste acceptance ▪ Fires (water used to fight fires) ▪ Waste placed in standing water ▪ Improper cover soil application ▪ Large working face
Odors/Particulate Emissions/Fires	▪ Steep side slopes ▪ Bulky, rigid nature of C&D debris ▪ Presence of gypsum drywall in waste stream, which is typical of C&D debris	▪ Improper cover soil application ▪ Large working face ▪ Possible acceptance of "hot loads"

4.3 Damage Case 2: Archie Crippen Excavation Site (Fresno County, California)

The Archie Crippen Excavation site was a 27-acre C&D debris processing and recycling facility located in Fresno, California, that primarily processed wood, concrete, and asphalt for recycling. The site began operating in 1980 as a processing, recycling, and storage facility for concrete and asphalt under a conditional use permit (CUP) issued by Fresno County (CIWMB 2003a). In January 2003, a fire broke out on a 5-acre, 20-ft high woody debris pile. Initial firefighter response appeared to extinguish the fire within a day, but significant subsurface combustion was apparently ongoing prior to discovery of the surface fire – ultimately, the surface fire re-emerged later, on the evening it was first discovered, and its intensity escalated quickly. Despite significant fire-fighting efforts, the pile burned for approximately another month, requiring a unified command response team that included fire fighters, the California Integrated Waste Management Board (CIWMB), US EPA, and others. The City of Fresno declared a local state of emergency and the Fresno Unified School District curtailed sports, recess, and outdoor physical activities during the period while the fire burned. After several additional months of site monitoring and remediation, all debris was removed from the site and the site was closed.

4.3.1 Site Description

The former Archie Crippen Excavation Site (site) is located in southwest Fresno, California, and is bordered by two roads to the east and south and by various businesses and households to the west and north. There are 471 households and one school located within a mile of the site (US EPA EJView 2012).

In 1980, the site received a conditional use pemit (CUP) from Fresno County to operate a 12 acre site as a concrete and asphalt processing facility and accept concrete, asphalt, and Group 3 wastes. Group 3 wastes are defined in the original CUP as:

> *nonwater soluble, nondecomposable inert solids, examples include but are not limited to:*
>
> > *Construction and demolition wastes such as earth, rock, asphalt paving fragments, inert plastics, plasterboard, and demolition material containing minor amounts of wood and metals.*

The phrase "minor amounts of wood and metals" was further defined as:

> *…approximately ten percent (by volume) of the total. Earth and rock from construction activities is considered waste if there is a potential for transport from the site to waters of the State.*

The operation plan for the facility shows that broken concrete and blacktop were crushed for resale to contractors. The original CUP was amended in 1982 to expand the working area and in 1983 the property was annexed into the City of Fresno. When the city annexed the property, the City of Fresno accepted the CUP without modification (CalRecycle 2004). At the time, there was no thorough review of business CUPs that were annexed into the City of Fresno (City of Fresno 2003). In 1994, the site was expanded onto an adjacent 15-acre parcel and the CUP was modified accordingly, with a total facility area of 27 acres. The site remained under the regulatory oversight of the Local Enforcement Agency of the City of Fresno, with minimal regulatory or enforcement action and inspections occurring on a "complaint only" basis for recyclable material operators, as per the City's Planning and Development Director (City of Fresno 2003).

The 27-acre parcel was divided up into distinct waste handling areas including wood processing, inert and metal processing, and mixed C&D processing (CIWMB 2003a). See ***Figure 4-4*** for an aerial view of the site as of August 2002. During operations, the processing areas contained different amounts of materials that were either processed or waiting to be processed.

4.3.2 Compliance History

As previously noted, the site generally operated for several years with minimal regulatory oversight, owing primarily to the lack of statewide C&D processing and recycling rules as well as local issues. A timeline of major events at the site including compliance is provided in ***Figure 4-5***.

A July 2001 inspection indicated no operational issues, but a fire at the site was noted in February 2002. Inspection records indicated concerns with the acceptance of unauthorized waste in August 2002, and in January 2003, the major fire broke out that encompassed a woody debris pile that encompassed approximately 5 acres. In May of 2003, the City of Fresno revoked the site's CUP for failure to comply with CUP conditions, specifically the provision that required operations to be "…limited to processing of concrete, asphalt and other Group III materials." The site had accepted materials such as auto wrecking junk, scrap iron, and excessive quantities of wood – the amount of wood at the site was estimated to comprise approximately 40% to 90% of the waste on site, far more than the 10% specified in the original CUP's definition of Group III materials. Furthermore, the CUP had a condition that allowed for a

maximum of 180 days of debris storage, but findings at the site indicated some debris had been present for at least 7 years. Another CUP violation included the violation of the uniform fire code (UFC). The UFC was adopted by the Fresno Municipal Code and includes requirements for access and water supply, and requirements for storage and processing of wood chips and debris (UFC 902.1, 903.1, 3008.1, 10

3.4.3.2, 103.4.3.3).

Figure 4-4. Aerial View of Archie Crippen Excavation Site as of August 2002 (Google Earth 2012)

4.3.3 Damage Assessment

On January 11, 2003, a fire was discovered in the main pile at the site in the 5-acre C&D debris storage pile on the west side of the property. The Fresno Fire Department (FFD) responded to the fire and after nearly 14 hours of firefighting, the fire was considered contained and firefighters left the site. Shortly after leaving the site, FFD received multiple phone calls indicating that the debris pile was on fire again, with reported large flames and heavy smoke. FFD was dispatched back to the site later that evening.

On January 13, the Air District issued an advisory due to high PM (2.5) levels, as well as an NOV due to numerous smoke complaints (US EPA 2003a, California State Auditor 2003). On January 14, the assistance of the CIWMB was requested as the fire intensified. CIWMB subsequently requested aid from the US EPA for air monitoring support. FFD did not have experience combating a fire of that size and

magnitude, thus the Office of Emergency Services was called in (CIWMB 2003a). A Unified Command was established to combat the fire and monitor the site, which involved the City of Fresno, Fresno County, CIWMB, US EPA, and the San Joaquin Valley Air Pollution Control District. During the main firefighting efforts, CIWMB funded the heavy equipment operations; the City of Fresno provided firefighters, and the US EPA provided air monitoring and health and safety support. A Joint Information Center was established to better communicate information to the media, and develop fact sheets and appropriate news releases. On January 23, both the city and county declared a local emergency (California State Auditor 2003).

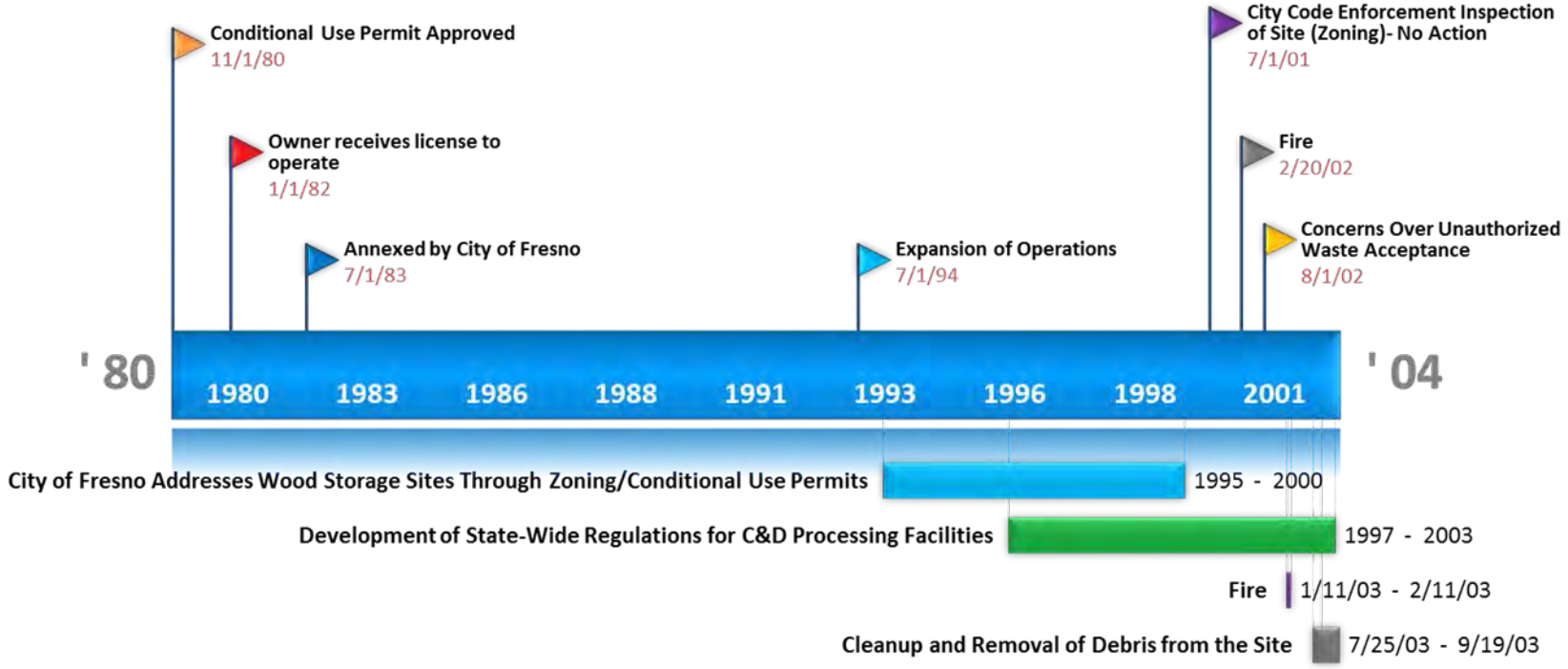

Figure 4-5. Compliance and Event Timeline at the Archie Crippen Excavation Site

Figure 4-6. Aerial View of the Archie Crippen Excavation Site Fire as of January 2003 (US EPA 2003a)

An aerial view of the fire at the site is provided in ***Figure 4-6***. Throughout the firefighting efforts, US EPA periodically conducted sampling of pile and perimeter emissions (US EPA 2003a). Air monitoring was also conducted throughout the entirety of the event. Fixed equipment and personal badges were used for carbon monoxide (CO), H_2S, and PM sampling. Volatile organic compounds (VOCs) were sampled from vents, on site, and off site at nearby schools. Metals were also sampled on site and off site at schools, while asbestos was monitored on site only. The air sample results showed that there were no toxic fume dangers, however PM and smoke irritants were present. The smoke and soot from the fire exacerbated Fresno's air quality, as the fire produced a cloud of smoke over the metropolitan area of Fresno, which impacted the most proximate neighborhood. Soot was found to be deposited on cars and homes within 1 mile of the site (California State Auditor 2003). During the first week of the fire, the Fresno Unified School District canceled all outdoor activities due to the health advisory from the San Joaquin Valley Air Pollution District from January 14 through January 16 (California State Auditor 2003). On January 25, a health screening was held at a nearby school, where volunteer medical experts interviewed residents, many of whom were found to have irritation and respiratory tract inflammation of because of the high levels of PM emitted (City of Fresno 2003).

Nearly 1 million gallons of water were used daily in firefighting efforts (CIWMB 2003a). Berms were built around the pile fire area to contain the large amounts of water applied to the pile (US EPA 2003b). CIWMB also had a mitigation plan in case issues with water retention arose; a pumping plan was in place to prevent off-site migration of the waters. The Fresno Regional Quality board conducted a preliminary assessment on the water runoff from the firefighting efforts and reported that there was little impact to ground or surface water (California State Auditor 2003). After approximately a month of continuous burning, the fire was extinguished in February 2003.

There were several factors that allowed the fire at Archie Crippen to become a massive fire event. One major factor was the fact that the debris pile consisted of one continuous mound without spaces in between (referred to as *fire breaks*). In addition to the surface fire that was initially present, investigators concluded that subsurface fires had been burning since at least before the January 2003 surface fire (see ***Figure 4-7***). Other factors that complicated the firefighting efforts were mainly the lack of adequate fire

breaks for proper access to the pile (California State Auditor 2003). As the firefighting went on, the pile was broken down into three 1-2 acre piles of nearly 20,000 to 25,000 yd^3 and a maximum height of 15 ft (CIWMB 2003a).

Figure 4-7. Wormholes in Debris Pile Fire Indicating Subsurface Combustion (US EPA 2003a)

Following the extinguishing of the Archie Crippen pile fire, efforts were conducted to stabilize the pile. Fire breaks were added and temporary access roads were added between the piles. Sampling occurred to evaluate the nature of the remaining materials in the pile. It was jointly decided by the City of Fresno, Fresno County, CIWMB, and US EPA that the most cost effective cleanup option for the fire debris was removal, transport, and disposal at a Class III nonhazardous MSWLF with a composite liner and leachate collection system. Mobilization began on July 28, 2003, and removal actions continued through September 2003. Temperature, CO, and CH_4 measurements were taken every morning in hot spot areas as part of working condition monitoring. In total, 4,111 truckloads transported 102,650 tons of material from the site. The cost of firefighting, stabilization, and clean-up efforts totaled nearly $6.5 million between the US EPA, CIWMB, State of California, and the City of Fresno (US EPA 2003c).

Overall the damage incurred at the site included emissions of particulate matter into the surrounding neighborhood, as well as the hazard of a large, uncontrolled fire. The site operated in a manner that was not consistent with the conditions of its previous conditional use permit, namely the storage of a large volume of wood-based products. The large debris pile was formed without fire breaks, and the site lacked an adequate water supply – although not a regulation, one of the lessons learned (as identified by Thalhamer, n.d.) was that storage of stockpiled woody C&D debris should follow procedures consistent with the National Fire Protection Association code for outside storage of forest products, which reads in part that wood piles should have

- a maximum pile turnover time of 1 year,
- a limitation to pile size, with a preference of numerous smaller piles,
- a means of measuring temperatures within the pile on a regular (e.g., weekly) basis,
- regular wetting to maintain moisture content and keep debris fines from drying out,
- constructed access roadways to the top of the pile and access to reach any part of the pile, and
- adequate water supply and fire hydrants so any part of pile can be reached by hose equipment.

4.4 Damage Case 3: Warren Landfill and Recycling Facility (Trumbull County, Ohio)

The Warren Recycling/Warren Hills C&D Landfill (site) accepted debris between 1994 and 2004. The site was the subject of a US EPA Superfund clean-up action from mid-2005 to mid-2006 to abate

emissions of H_2S into surrounding residential communities. Due to the presence of H_2S at elevated concentrations (one reading found a concentration of 95 ppm in residential ambient air), the ATSDR categorized conditions in the neighborhoods surrounding the site as presenting an urgent public health threat. More than 800 odor complaints were logged from more than 100 individuals (OEPA 2004a). In addition to fugitive emissions of H_2S, there have also been groundwater and surface water impacts resulting from site operations that have been measured following cessation of site operations and at least one documented instance of a prolonged (5-month) onsite subsurface fire.

4.4.1 Site Description

The site is an inactive landfill situated within approximately 240 acres located in Warren, Ohio. The site is co-located with a municipal solid waste transfer station in a mixed commercial and residential area and was originally constructed in a low-lying area adjacent to a wooded marsh or swamp (Tetra Tech 2004, ATSDR 2006). The site was permitted to accept up to 1,500 tpd of C&D (OEPA 1994), and accepted waste by truck and by rail. Two schools (Labrae High School and Leavitt Elementary School) were located within 1 mile of the site. Labrae High School was demolished in March 2006 and Leavitt Elementary School was abandoned. ***Figure 4-8*** shows an aerial view of the site with the approximate extents of the different fill areas.

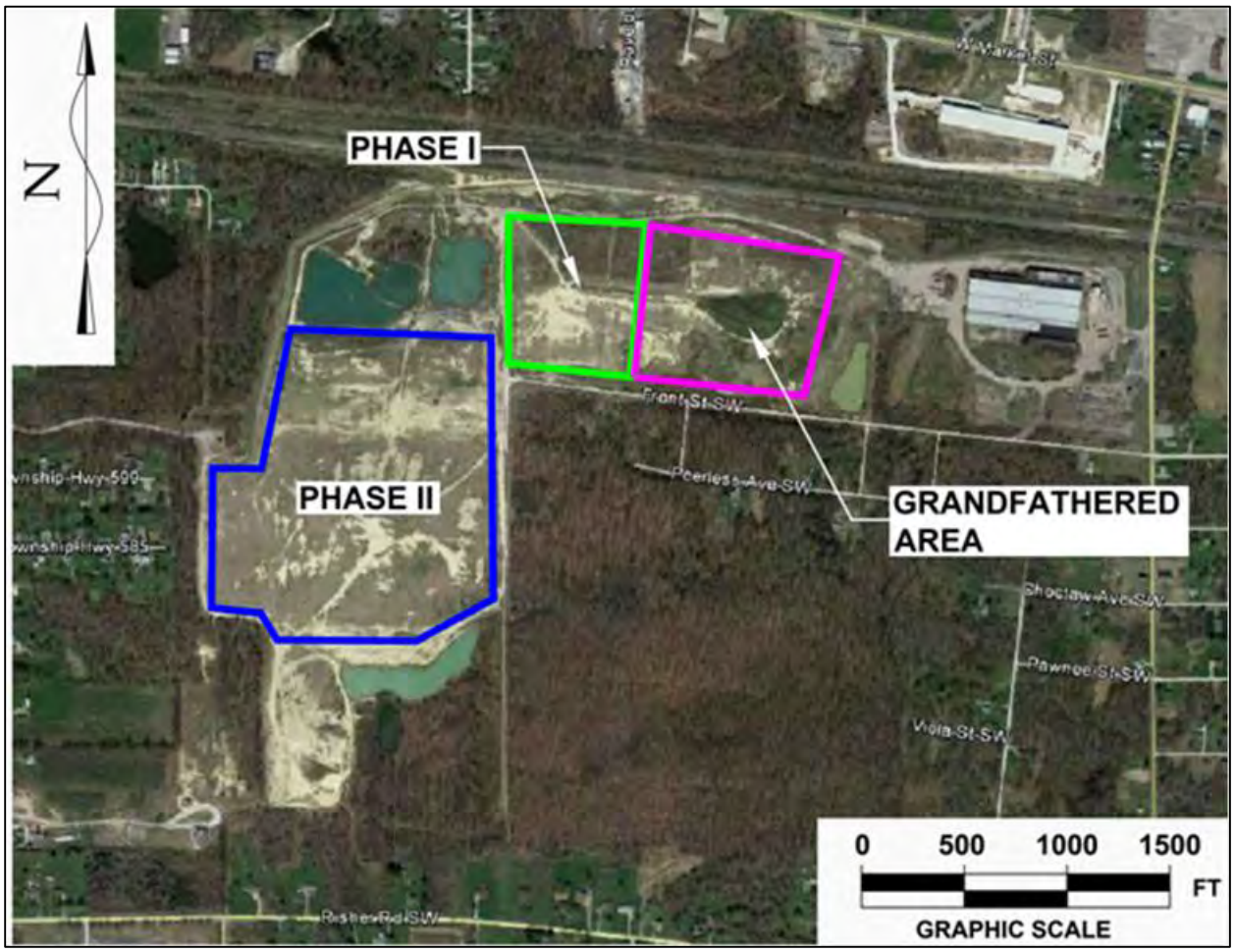

Figure 4-8. Site Layout of the Warren Recycling Landfill with Approximate Landfill Phase Extents (April 2012 Aerial Imagery from Google Earth)

The footprint of the disposal area occupies approximately 62 acres and is divided into three separate sections known as the "Grandfathered" area, Phase I, and Phase II. The Grandfathered area has a disposal footprint of approximately 17 acres and is unlined. The Phase I section started receiving waste in 1999 and has a disposal footprint of nearly 15 acres and has an in-situ soil liner with a leachate collection system (Civil and Environmental Consultants, Inc. [CECI] 2003). Phase I is piggybacked over a portion of the Grandfathered area. Phase II has a disposal footprint of approximately 30 acres and includes a tire drainage layer, a bottom liner and a leachate collection system (Durno 2005). Based on historic drawings and an OEPA inspection, there appear to be at least three leachate riser pipes that have been used to remove leachate from low points in the saw-tooth bottom liner system across the site; the bottom liner for Phase II is located a maximum of approximately 15 ft below existing grades while the bottom liner for Phase I is a maximum of nearly 20 ft below existing grades (PCR 2001, PCR 2003).

The elevation of existing grades surrounding the site ranges from approximately 900 to 910 ft above mean sea level. The Mahoning River runs west to east approximately 1,500 ft north of the site, and there are two tributaries that border both the eastern and western portions of the site that empty into the river: Duck Creek, located approximately 1,700 ft west of the site, and an unnamed tributary directly east of the site.

According to a hydrogeologic site investigation report (CECI 2003), the underlying geologic profile is divided into three general layers. The uppermost (shallow) layer consists of silt/sand unconsolidated overburden, and ranges in thickness from 20 to 50 ft. The intermediate layer is comprised of Sanbury Shale bedrock, which has two noted fracture zones and ranges from about 60 to 95 ft thick. The deepest layer is made up of Berea Sandstone, with its uppermost boundary located approximately 95 to140 ft below ground surface. This layer represents the uppermost aquifer system, and is the major water-bearing unit for approximately 25 groundwater supply wells within a mile of the site (CECI 2003). An OEPA groundwater monitoring report from May 2010 sampling indicates at that time there were 17 total operable (not dry) groundwater monitoring wells that comprised the entire groundwater monitoring network; 11 installed in the uppermost shallow zone, 3 in the intermediate zone, and 3 in the deep zone.

Historically, the site has been used for various industrial purposes as far back as the 1920s, when a brickyard operation existed. This was followed by a steel-stamping operation and then a trucking company. The site was purchased by Warren Recycling, Inc. (WRI) in 1994, when it began operation as a C&D landfill (ATSDR 2002).

4.4.2 Compliance History

C&D disposal facilities in Ohio are regulated through OAC 3745-400. C&D sites are also regulated through permits-to-install (which provide operational and air pollutant discharge standards) and permits associated with stormwater and leachate discharge (e.g., National Pollutant Discharge Elimination System and wastewater treatment plant discharge permits), as applicable. Current OAC requirements for C&D disposal facilities include construction of a bottom liner with a leachate collection system, maintaining less than 1 ft of leachate depth (head) on the bottom liner, constructing and maintaining a groundwater monitoring well system for sites where waste was placed post-September 1996 with at least annual groundwater sampling, and placing a weekly non-combustible material cover over deposited C&D.

Compliance and enforcement information dating back to 1994 was reviewed and is summarized below. A timeline of major non-compliance events and related activities is presented in ***Figure 4-9***.

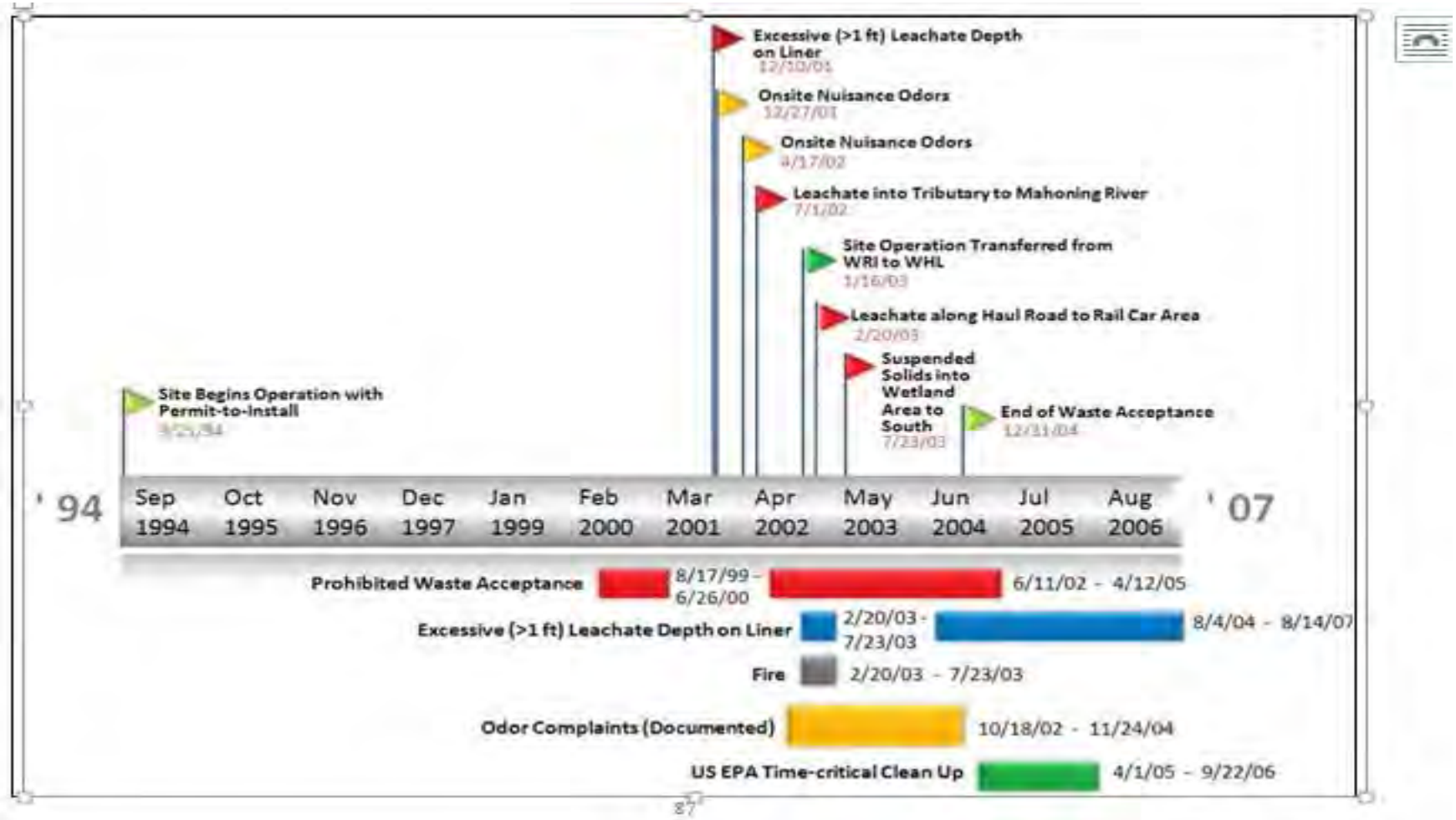

Figure 4-9. Timeline of Non-Compliance Events and US EPA Time-critical Clean Up (Bars Represent Recurring non-Compliance Issues as Noted in OEPA and WHCD Inspection Logs)

1994–2002

Several Warren City Health District (WCHD) inspections noted the acceptance of prohibited (non-C&D) waste, including industrial waste between August 1999 and June 2000. Some examples of non-C&D materials accepted over this period included rubber manufacturing parts, car parts, drum containers, and paper products. A November 2002 inspection report recorded that the industrial waste deposited during this time was never removed, and Tetra Tech (2004) noted that a 1999 criminal investigation resulted from its acceptance.

In fall 2001, the OEPA received numerous odor and health-related complaints from residents living in neighborhoods in the vicinity of the site including reports of nausea, headache, vomiting, eye irritation, fatigue, dizziness, and memory loss (Colledge 2005). These complaints and a subsequent petition submitted to ATSDR prompted an investigation to evaluate exposure levels to area students, residents, and workers from May to June 2002. The resulting Health Consultation, published 12 September 2002, categorized the site as a "public health hazard."

Other compliance issues noted included the first instance of an odor issue (December 2001), which was identified as "similar to rotting eggs." Additional nuisance odors were noted during an April 2002 inspection. Surface water impacts from leachate outbreaks from the eastern portion of the closed landfill were noted during a July 1, 2002, OEPA inspection.

2002–2007

Starting in June 2002, at least 23 inspection reports documented the acceptance of prohibited waste, primarily involving MSW. During this period, unidentifiable pulverized material was accepted at the site as documented during February and March 2003 inspections; sometimes this material was directly applied to the working face from rail cars without pre-screening. OEPA estimated that approximately 630,000 to 705,000 tons of pulverized C&D including powdered gypsum drywall were accepted from early 2003 to mid-2004 (US EPA 2006b).

Two more instances of surface water impacts occurred in 2003. The first involved the seepage and runoff of leachate along the site's haul road to the rail car unloading area. The second occurred as a result of the uncontrolled discharge of stormwater to a wetland area to the south of the site. The inspection report noted that suspended sediments/solids had not settled out of the stormwater prior to discharge.

From February to July 2003, a subsurface fire reportedly smoldered at the site. Four separate OEPA inspections recorded smoke emissions from various landfill surfaces and areas of localized subsidence during this time period. One inspection near the start of this fire event found that deposited waste was placed without appropriate compaction, and two 2004 inspections also noted improper compaction.

According to OEPA inspections in 2003 and 2004, cover was not used regularly and stormwater was not diverted from the working face, allowing leachate to collect in permanent leachate ponds at the toe of landfill side slopes. OEPA stated odor problems became more serious during this period; residents north and west of the landfill complained of "rotten egg" odors and negative health effects. Leachate head on the liner greater than 1 ft was reported from February through July 2003.

An Exposure Investigation published by ATSDR concluded H_2S gas presented an "urgent public health threat" to the neighboring community (ATSDR 2003). This was based on an ambient air monitoring event, summarized in Section 4.4.3. Federal, state and local agencies required the site owner to develop a closure and remedial plan, but the owner did not comply with the order (US EPA 2006b).

On 1 July 2003, a Consent Order and Permanent Injunction were signed which required the site to comply with numerous provisions, including those relating to recurring non-compliance issues including:

- Not accept material other than C&D for disposal at the site.
- Only unload and screen waste in a designated unloading zone.
- Submit and implement a final closure plan for existent and the future Phase II area in the appropriate timeframes.
- Operate the site in a manner to prevent fires.
- Manage and control leachate (e.g., maintain and monitor the leachate collection systems in Phase I and II).
- Complete a hydrogeological investigation and implement a groundwater monitoring program.

On August 20, 2004, an OEPA inspection noted cracks in the cover soil at the toe of the southeastern slope of Phase II revealed stained black soil suspected as a result of H_2S emissions. Nuisance H_2S odors were detected during WCHD inspections in November and December 2004 through the end of site C&D filling operations.

Even though a time-critical clean up action was executed by US EPA from mid-2005 to fall 2006, part of which involved pumping out more than 13.4 million gallons of leachate (Durno 2006), head-on-liner exceedances were recorded in OEPA inspection reports from August 2004 until August 2007. Following the completion of site clean-up activities, US EPA turned over operation and maintenance of the leachate management system to the site owner (Durno 2006).

On March 28, 2007, a Stipulation of Finding of Contempt and Joint Motion to Suspend Entry of Contempt Penalties was signed, which brought five charges of contempt against the site owner regarding failure to meet conditions listed in the Consent Order issued in July 2003. These charges included failure to properly manage and control leachate, submit closure and post-closure plans, implement groundwater monitoring, and pay the previous stipulated penalty fee.

A Consent Order that replaced the 2003 Consent Order was signed March 17, 2008; the terms of the order that applied to site operation include the following:

- Apply at least 12 in. of cover soil to all exposed waste areas and all areas with greater than 2 in. of erosion. The site owner was required to submit a cover and seeding/vegetation plan prior to initiating supplementary cover activities.
- Maintain less than 1 ft of leachate depth on the bottom liners of the Phase I and Phase II portions of the site, and maintain a pumping log for each day leachate was pumped.
- Continue perimeter H_2S monitoring at least once per week and monitor H_2S concentrations across the entire site at least once per month.
- Inspect the entire facility for cover integrity and odors/gases once per month.
- Maintain all leachate collection system and pumping equipment.

4.4.3 Damage Assessment

This section presents a discussion of damage based on review of historical reports, site inspection documents, and related information on the site, with particular focus on odors caused by H_2S emissions and groundwater impacts as demonstrated by monitoring conducted at the site.

H_2S Emissions

Figure 4-10 shows a plot of the various locations around the landfill where H_2S odors were identified (or recorded as a "rotten egg" smell) based on WCHD odor monitoring reports and investigation logs from October 2002 through November 2004. There are 35 unique addresses represented in this plot, with the farthest odor complaint originating from nearly two-thirds of a mile away from the site.

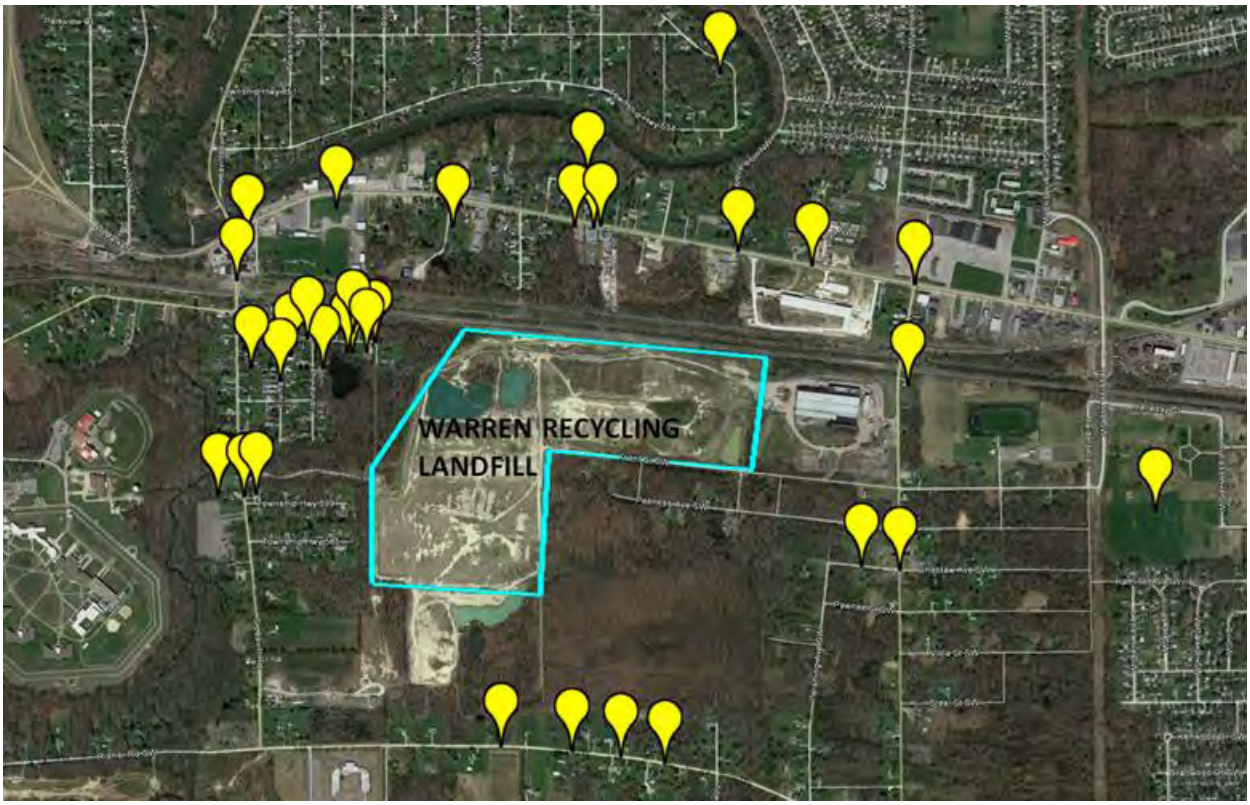

Figure 4-10. Warren Recycling Landfill Community Odor Complaints Between 2002 and 2004 (April 2012 Aerial imagery from Google Earth)

There were at least six different area residential and on-site H_2S monitoring events between 2002 and 2006. ***Table 4-6*** provides a summary of the different H_2S and sulfur compound monitoring events including the date taken, organization performing the monitoring, the location(s) of H_2S monitoring, the equipment used, the maximum H_2S concentration detected, and a discussion of results.

Table 4-6. Summary of Major H_2S Monitoring Events at the Warren Recycling Landfill

Date	Sampler and Data Source	Location	H_2S Monitoring Equipment	Max. H_2S Concentration(s)	Discussion
7 May – 3 June 2002	MS Consultants, Inc. (ATSDR 2002)	5 Monitoring Points in Surrounding Area (including LaBrae High and Leavitt Elementary Schools)	City Technology Triple Plus Monitors (UK)	13.1 ppm	The Health Consultation reviewing the results of this monitoring noted a lack of adequate QA/QC measures, potential interference with carbon monoxide and nitrous oxide concentrations, instances of tampering or malfunctions with the monitors, and times where negative concentrations were recorded. However, ATSDR concluded site area conditions represented a "public health hazard."
14 Nov. 2002 – 8 March 2003	ATSDR (2003)	6 Residential Locations – Indoor and Outdoor	Zellweger Analytics Single Point Monitors (with ChemKey and Chemcassette Detection Systems)	6.1 ppm outdoor (> 6 ppm for 15 minutes) 38 ppb indoor (> 30 ppb for 2 hours)	The manufacturer of the equipment claimed that readings are accurate within 20% – 25% of the true value and have a precision of 10% or greater. As a result of this monitoring, ATSDR classified area conditions as an "urgent public health hazard."
15 Dec. 2003 – 21 July 2004	Area Resident (ATSDR 2006)	Area Residence	SUMMA Canisters (6), Tedlar Bags (2)	Indoor: ▪ Dimethyl Disulfide 28 ppb ▪ Methyl Mercaptan 12 ppb Outdoor: ▪ Dimethyl Disulfide 180 ppb ▪ Methyl Mercaptan 750 ppb ▪ Dimethyl Sulfide 530 ppb ▪ n-Butyl Mercaptan 83 ppb ▪ H_2S 60 ppb	A resident at a single location historically impacted by H2S odors took indoor and outdoor grab samples during odor events for laboratory analysis. Of six SUMMA canister samples taken, only one had detectable concentrations of sulfur compounds. The concentrations from the two Tedlar bags were determined using a calibration curve based on laboratory control samples at concentrations up to 1000 times greater than those reported.

(continued)

Table 4-6. Summary of Major H_2S Monitoring Events at the Warren Recycling Landfill (continued)

Date	Sampler and Data Source	Location	H_2S Monitoring Equipment	Max. H_2S Concentration(s)	Discussion
June – Aug. 2004	Area Residents (Colledge 2005)	Area Residents and Workers (Personal Badges). Five Residences (Ambient Air Monitors), Odor Events	Personal Badges, Ambient Air Monitors, hand-held monitor	95 ppm (near sewer manhole cover on Lover's Lane just south of Mahoning River)	This reading is close to the National Institute for Occupational Safety and Health immediately dangerous to life or health exposure level of 100 ppm. The reading prompted US EPA to notify the site owner to stop pumping leachate into the sewer. Leachate was transferred to the wastewater treatment plant by truck.
1 Sept. – 6 Oct. 2004	Tetra Tech EM, Inc. (2004)	3 Area Residences	Zellweger Analytics Single Point Monitors	539 ppb > 120 ppb for 24 minutes > 100 ppb for 101 minutes (All max. readings from residence immediately NW of site)	Because these readings exceeded the American Industrial Hygiene Association recommended Emergency Planning Guideline of 100 ppb for up to a maximum of one hour, it was concluded that a US EPA time-critical removal action was warranted for the site.
17–18 May 2005 and 25–27 July 2006	US EPA (2006)	Landfill Surface	Low-level H_2SMonitor	165 ppm (before clean up) 0.043 ppm (following clean up)	H_2S monitoring results indicate that cleanup work performed by US EPA Emergency Rapid Response Services and the Superfund Technical Assessment and Response Team was effective in reducing H_2S emissions from the site.

US EPA began an interim cleanup 25 April 2005 to reduce the immediate threat posed by H2S emissions. This work involved cleanup of the southwest section of the landfill, which, as determined in May 2005, was the only portion (of Phase II) of the site at the time which was producing H2S gas at concentrations considered an immediate public health risk (US EPA 2006b). This cleanup involved the following:

- Collecting all loose C&D and place on the open face, and then covering the exposed waste with a temporary clay cap. US EPA estimated that approximately 20,000 tons of material were relocated.
- Draining and filling in (with clay) portions of the southwest section of the site which had standing water
- Grading the surrounding land and constructing a large ditch in order to divert stormwater away from the landfill in the future.
- Providing a compacted clay cap on southwest portion of the landfill.
- Removing a large amount of leachate "trapped" inside the landfill using system of pipes and pumps to draw from both the landfill and surrounding ponds.

By May 2006, more than 13 million gallons of leachate had been collected, treated, and discharged. Leachate levels over the leachate collection pad dropped from 13 to 6 ft. A final survey of H_2S emission concentrations was performed in July 2006, where a low-level H_2S monitor was used to collect surface data on the landfill on a 50-ft interval grid. Sampling during similar weather conditions revealed maximum H_2S concentrations were reduced from 165 ppm in May 2005 to 0.043 ppm in July 2006.

The factors related to the H_2S emissions included non-compliance issues as well as other factors unrelated to compliance. As described earlier in Section 4.2 and in Section 3, the acceptance of drywall and C&D landfill conditions can lead to the formation of H_2S. However, a unique factor at the site that contributed to the high emission levels observed include the build-up of leachate at the bottom of the lined cells and the acceptance of pulverized C&D debris. The build-up of liquid was observed to result in the saturation of waste near the bottom of the landfill, which created even more favorable conditions for H_2S production (compared to a landfill that does not have built-up liquids). Furthermore, the disposal of size-reduced C&D debris (which included gypsum drywall) created a larger specific surface area which can promote the formation of H_2S compared to larger pieces of debris.

Groundwater

Potentiometric contour plots from OEPA groundwater sampling reports show that groundwater in the shallow zone has a relatively complex flow path (OEPA 2008, 2009b, 2011b). Shallow groundwater in the Phase I and Grandfathered sections of the landfill generally flows east or northeast across the site while the groundwater below the Phase II area flows west or northwest. A groundwater monitoring plan and system was required in the July 2003 consent order and a total of 22 piezometers were installed from August to October 2003, however, the operator never implemented groundwater monitoring. OEPA voluntarily initiated quarterly groundwater sampling in November 2005.

The majority of groundwater monitoring events involved sampling from monitoring wells installed in the surficial zone, typically including 11 wells – three upgradient (MW-3SA, MW-3SB, and MW-5S) and eight downgradient. Samples were taken from both the intermediate and deep zones as well.

Quarterly sampling was concluded in August 2006, when OEPA transitioned to a semiannual sampling schedule, the first of which took place in November 2006. OEPA performed a statistical analysis of the November 2006 results and found that several downgradient wells showed statistically significant elevated parameter concentrations above those measured in upgradient wells – the elevated parameters included potassium, ammonia, COD, chloride, and sulfate.

Table 4-7 presents a summary of the parameters with noted exceedances of Ohio MCLs measured in groundwater monitoring wells installed in the surficial aquifer. Each parameter (with the exception of filtered thallium and filtered arsenic) exhibited an exceedance of the Ohio MCL at least once for all parameters listed in the table in both upgradient and downgradient wells. An assessment of the monitoring data suggests that chloride, sulfate, iron, manganese, and thallium were greater in downgradient wells compared to upgradient wells, though detailed statistical comparisons are difficult because of the small number of sampling events for each well. Measured concentrations for other parameters (e.g., aluminum, arsenic) are variable and a distinct difference in upgradient and downgradient concentrations was not discernible. Evaluations conducted by OEPA (2011) found statistically significant differences in alkalinity, ammonia, chloride, COD, magnesium, potassium, sodium, and sulfate between background wells and at least one downgradient well, generally consistent with observations from 2006 groundwater monitoring event analysis.

Monitored Parameter	Units	MCL	Number of Measurements (Exceedances of MCLs)	
			Upgradient	Downgradient
Chloride	mg/L	250 (S)	18 (1)	56 (12)
Sulfate	mg/L	250 (S)	18 (11)	56 (48)
Aluminum	mg/L	.05 (S)	16 (14)	48 (41)
Arsenic	µg/L	10	16 (13)	48 (12)
Filtered Arsenic	µg/L	10	6 (4)	18
Iron	mg/L	0.3 (S)	16 (15)	48 (46)
Filtered Iron	mg/L	0.3 (S)	6 (3)	18 (11)
Lead	µg/L	15	16 (1)	48 (2)
Manganese	mg/L	.05 (S)	16 (11)	48 (42)
Filtered Manganese	mg/L	.05 (S)	6 (4)	18 (16)
Thallium	µg/L	2	16 (2)	48 (12)
Filtered Thallium	µg/L	2	6	18 (7)

Note: 1. (S) denotes a secondary drinking water standard.

Table 4-7. Summary of Groundwater Monitoring Parameters Exceeding MCLs at Warren Recycling C&D Landfill (2007 – 2010 Monitoring Data)

As discussed, the landfill consists of a combination of unlined and lined cells. Furthermore, the site has a documented history of leachate build-up on the lined areas. Given the mix of lined and unlined disposal areas at the site, it is difficult to assess the efficacy of the liner and leachate collection system. However, the data reviewed suggest that some impacts to groundwater from historical landfill operations occurred.

4.4.4 Summary

Table 4-8 presents a summary of the damages observed at the site and the potential contributing factors, including those that may be related to permit non-compliance and those that are not related to permit non-compliance. Ultimately, a combination of factors related and unrelated to permit compliance appear to have resulted in the conditions observed at the site. In the case of H_2S emissions, the nature of the materials disposed and the anaerobic, moist conditions that can form within C&D landfills likely would have led to the production and emission of H_2S regardless of whether the facility complied with applicable rules. However, the acceptance of large amounts of pulverized debris, which results in an increased specific surface area of the debris and thus makes the gypsum drywall more susceptible to conversion into H_2S, coupled with the improperly functioning leachate collection system that allowed a significant quantity of leachate to build up within the lined cells, appears to have greatly enhanced conditions that cause the production and emission of H_2S.

As for groundwater impacts, directly tying the elevated constituent levels observed to one specific activity is difficult. The facility had an unlined cell as well as cells with improperly functioning leachate collection systems, thus, it is expected that both conditions likely contributed to the groundwater impacts observed at the site. So ultimately, a combination of permit non-compliance as well as the presence of the unlined cell (which was built before C&D landfills required liners and leachate collection systems in Ohio) contributed to the groundwater impacts observed at the facility.

Table 4-8. Summary of Site Environmental Damages and Potential Contributing Factors Related to and Not Related to Facility Non-Compliance at the Warren Recycling Landfill

Damage	Potential Contributing Factors Not Related to Facility Non-Compliance	Potential Contributing Factors Related to Facility Non-Compliance
H_2S Emissions	▪ Acceptance of gypsum drywall ▪ Requirement to apply cover weekly (more frequent application may have been required to reduce H2S emissions to acceptable levels)	▪ Acceptance of unidentifiable (pulverized) waste ▪ Failure to apply weekly cover ▪ Failure to install and maintain final cover ▪ Improper operation of leachate collection system ▪ Improper surface water management
Groundwater Impacts	▪ Presence of an unlined cell (built before liner and leachate collection requirements) ▪ Nature of C&D debris causing elevated constituents identified at unlined C&D debris landfills	▪ Improper operation of leachate collection system (allowing build-up of leachate on liner) ▪ Prohibited and unidentifiable waste acceptance ▪ Failure to install and maintain final cover ▪ Improper surface water management

The problems that were observed at the site were remediated as part of a Superfund cleanup action by the US EPA. The clean-up effort, which cost approximately $4 million (US EPA 2006c), primarily focused on the control of H_2S emissions, which was largely addressed through the removal of significant quantities of leachate that were built up at the landfill.

4.5 Summary of Detailed Damage Cases

Three damage cases located in different regions of the US comprising different types of operations (disposal and recycling) were examined. In each of the three damage cases, a combination of permit non-compliance issues as well as issues that occurred which were consistent with the facility's permit led to damage that was manifested as groundwater, surface water, odor emission, and/or fire-related impacts.

The evaluation specifically suggested that damages that occurred at these facilities may have been prevented with the inclusion or implementation of best management practices. Furthermore, the dissemination of the lessons learned from these damage cases (as well as damage cases from other facilities in other states) would provide a valuable resource for regulators and the regulated community. The development of a best practice guide for C&D management at landfills and recycling facilities could promote sustainable practices that reduce the likelihood of the formation of conditions that could result in negative environmental impacts.

5. Summary and Recommendations

The results of the analysis conducted in this study show that the rules for the management of C&D debris vary, sometimes substantially, from one state to another, both in terms of operational requirements and design, construction, and siting requirements. The inventory of C&D landfills is expected to be a fairly accurate representation of the universe of active C&D landfills in the US as of the time of this writing, but the inventory of C&D recycling facilities (which is, to the knowledge of the project team, the most extensive inventory of C&D recycling facilities in the US compiled to date) contains several data gaps, which is mostly a function of the exemption from solid waste regulation that is afforded to recyclers of certain C&D debris materials and the fact that many states do not have rules specific to C&D recycling.

The inventory of damage sites in the US was limited by several factors, but the examination of large-scale statewide data suggests that the universe of C&D sites impacting the environment is likely far greater than the inventory that was developed through contacts with state regulatory representatives. The detailed assessment of three damage cases each shows that a combination of factors, both related and unrelated to permit non-compliance, plays a significant role with regard to the cause of damage. These damage cases highlight the fact that damage may occur in several forms (e.g., groundwater impacts, fires and associated emissions, and odorous emissions related to H_2S) and the impacts can be significant. In addition to the human health and environmental impacts caused by these damage sites, the economic burden was significant as well – the closure or remediation of each of these sites exceeded $3 million.

In light of these observations, several recommendations are made that would help to augment the results identified in this report and provide states and communities with improved information regarding C&D debris management in the US:

- Enhance the site damage inventory developed in this analysis by conducting a formal survey of states to include regional and district representatives who are responsible for compliance and enforcement.
- Compile and examine additional large-scale data sets from other states in the US to provide a more complete picture of the range of constituent concentrations observed at sites in other states in the US. The data set would ideally include groundwater, leachate, and gas-related data (e.g., CH_4 measured at landfills and in monitoring probes and H_2S measured at landfills within the waste or in ambient air). Although the US EPA (2012) will be publishing an updated best management practices guide for preventing and controlling H_2S emissions from landfills, additional operational data from sites would inform states and communities of concentrations that may be measured at C&D landfills and enhance overall technical body of knowledge.
- Further examine the extent of issues and experiences with fires at C&D landfills. This may include causes but also an exploration and potential development of best practices to prevent and control landfill fire events.
- Develop a best management practices tool for C&D disposal and recycling facilities. As this report demonstrated, damage at the three facilities examined was caused by a combination of permit non-compliance issues and conditions unrelated to permit non-compliance. Compiling best practices based on discussions with facilities throughout the US would serve as a valuable tool for regulators and the regulated community to understand common practices that may lead to damage and methods to mitigate or avoid these practices. A best management practices tool could also be used as an opportunity to convey some of the lessons learned in this report and in other studies and convey the potential environmental damage that may occur at C&D disposal and recycling facilities.
- Develop improved databases related to the number of C&D recycling facilities as well as C&D debris management in the US. Previously published information estimating C&D debris

generation and management in the US have shown significant spread (a difference of a factor of five, depending on the methodology used and the materials included in the estimate), and the compilation of generation and management data on a more frequent basis using a consistent methodology would help US EPA benchmark improvements (similar to what is currently done in the MSW facts and figures published by US EPA) and identify additional opportunities for the US EPA to provide tools to help states manage materials more sustainably.

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